

An Individualized Kinetic-Chain–Based Physiotherapy Protocol for Patellofemoral Pain: A Prospective Interventional Study

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DOI: <https://dx.doi.org/10.51584/IJRIAS.2026.110200093>

Received: 21 February 2026; Accepted: 26 February 2026; Published: 14 March 2026

ABSTRACT

Background: Patellofemoral pain (PFP) is one of the most common causes of anterior knee pain in physically active individuals and young adults. Altered lower-limb biomechanics, proximal muscle weakness, poor neuromuscular control, and faulty movement patterns along the kinetic chain contribute to abnormal patellofemoral joint loading. Conventional physiotherapy approaches focusing solely on the knee may fail to address these contributing factors.

Objective: To evaluate the effectiveness of an individualized kinetic-chain–based physiotherapy protocol on pain intensity, functional capacity, and movement quality in individuals with patellofemoral pain.

Methods: A prospective interventional study was conducted on 40 participants aged 18–35 years diagnosed with patellofemoral pain. Participants underwent a 6-week individualized kinetic-chain–based physiotherapy protocol focusing on hip and trunk strengthening, lower-limb alignment, movement retraining, and patellar loading control. Outcome measures included the Numerical Pain Rating Scale (NPRS), Kujala Anterior Knee Pain Scale (AKPS), and single-leg squat quality assessment. Pre- and post-intervention scores were analyzed using paired statistical tests.

Results: A significant reduction in pain intensity (NPRS) and improvement in functional outcomes (AKPS) were observed post-intervention ($p < 0.05$). Movement quality during single-leg tasks showed marked improvement, with reduced dynamic knee valgus and better trunk control.

Conclusion: An individualized kinetic-chain–based physiotherapy protocol is effective in reducing pain and improving function and movement quality in individuals with patellofemoral pain. Addressing proximal and distal contributors within the kinetic chain enhances rehabilitation outcomes beyond knee-focused interventions alone.

Keywords-Patellofemoral pain, kinetic chain, physiotherapy, anterior knee pain, movement retraining, rehabilitation

FUNDING ACKNOWLEDGMENT

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

INTRODUCTION

Patellofemoral pain (PFP) is one of the most common causes of anterior knee pain among adolescents, young adults, and physically active populations. It is typically aggravated by activities that increase patellofemoral joint

loading such as squatting, stair climbing, running, jumping, and prolonged sitting (1). PFP is associated with long-term functional limitations, reduced participation in physical activity, and decreased quality of life. Longitudinal studies indicate that a large proportion of individuals with PFP continue to experience persistent or recurrent symptoms several years after initial onset, highlighting the chronic and relapsing nature of the condition (2).

The etiology of PFP is multifactorial and cannot be attributed solely to local knee pathology. Traditional explanations focusing on patellar maltracking, quadriceps weakness, and soft tissue tightness are now considered insufficient to explain symptom development and persistence (3). Contemporary biomechanical models emphasize the role of proximal and distal contributors along the lower-limb kinetic chain. Altered hip kinematics, reduced hip abductor and external rotator strength, impaired trunk control, and excessive foot pronation can lead to abnormal femoral internal rotation and adduction during functional activities, resulting in increased lateral patellofemoral joint stress (4).

Proximal muscle dysfunction, particularly weakness of the hip abductors and external rotators, has been consistently associated with dynamic knee valgus during single-leg functional tasks (5). Dynamic knee valgus increases compressive and shear forces at the patellofemoral joint and is strongly associated with pain severity and functional impairment in individuals with PFP. Performance during tasks such as the single-leg squat has been shown to reflect hip muscle function and frontal-plane knee control, providing clinically relevant insight into movement impairments (6).

In addition to proximal factors, trunk stability plays a crucial role in controlling lower-limb alignment during dynamic activities. Poor lumbopelvic control during weight-bearing tasks can result in compensatory trunk lean and pelvic drop, increasing medial knee displacement and patellofemoral joint loading (7). Distal contributors, including excessive foot pronation and impaired intrinsic foot muscle function, may further exacerbate tibial internal rotation and femoral motion, compounding abnormal patellofemoral loading. These findings highlight the interconnected nature of the kinetic chain in the pathomechanics of PFP (8).

Conventional physiotherapy interventions for PFP have traditionally emphasized quadriceps strengthening, patellar taping, and local symptom management. Although these approaches may provide short-term symptom relief, they may not adequately address underlying movement impairments and kinetic-chain dysfunction (9). Emerging evidence suggests that rehabilitation programs incorporating hip strengthening and movement retraining result in greater improvements in pain and lower-limb kinematics compared to knee-focused exercise programs alone (10).

The kinetic-chain concept in physiotherapy emphasizes that optimal movement and load distribution depend on coordinated function of the trunk, hip, knee, and foot segments. Individualized rehabilitation programs that target specific movement deficits may therefore offer superior clinical outcomes (11). Despite increasing support for kinetic-chain-based rehabilitation in patellofemoral pain, there remains a lack of standardized individualized protocols in clinical practice. This highlights the need to evaluate the effectiveness of individualized kinetic-chain-based physiotherapy interventions in reducing pain and improving functional outcomes in individuals with patellofemoral pain (12).

METHODS

A prospective interventional study was conducted over a period of six weeks at the outpatient physiotherapy department of a tertiary care institute. 40 participants aged 18–35 years with clinically diagnosed patellofemoral pain of at least three months' duration were recruited using convenience sampling. Patellofemoral pain was identified based on the presence of diffuse anterior knee pain aggravated by at least two functional activities such as stair climbing, squatting, running, or prolonged sitting. Individuals with a history of knee surgery, patellar instability, ligament or meniscal injury, osteoarthritis, neurological disorders, or inflammatory joint conditions were excluded to avoid confounding factors. Written informed consent was obtained from all participants prior to enrollment, and the study protocol was approved by the Institutional Ethics Committee.

Baseline assessment included demographic data and clinical evaluation followed by outcome measurement using the Numerical Pain Rating Scale (NPRS) to assess pain intensity, the Kujala Anterior Knee Pain Scale (AKPS) to evaluate functional limitations, and the Single-Leg Squat (SLS) test to assess movement quality and lower-limb alignment. The SLS was performed on the symptomatic limb, and movement quality was visually assessed by a trained physiotherapist in the frontal and sagittal planes, focusing on trunk control, pelvic stability, femoral adduction and internal rotation, dynamic knee valgus, and foot posture.

All participants underwent a six-week individualized kinetic-chain–based physiotherapy protocol delivered three times per week. The intervention was tailored based on individual movement impairments identified during baseline assessment and included hip abductor and external rotator strengthening, core stabilization exercises, quadriceps strengthening with controlled patellofemoral loading, foot intrinsic muscle strengthening, functional movement retraining during tasks such as single-leg squat and step-down activities, and education regarding activity modification and load management. Exercise progression was based on pain tolerance and movement quality.

Post-intervention outcome measures were recorded at the end of six weeks using the same assessment tools. Data were analyzed using appropriate paired statistical tests to compare pre- and post-intervention scores, with the level of significance set at $p < 0.05$.

RESULTS

All 40 participants completed the six-week individualized kinetic-chain–based physiotherapy program, and no adverse events were reported during the intervention period. Pre- and post-intervention comparisons demonstrated statistically significant improvements across all three outcome measures.

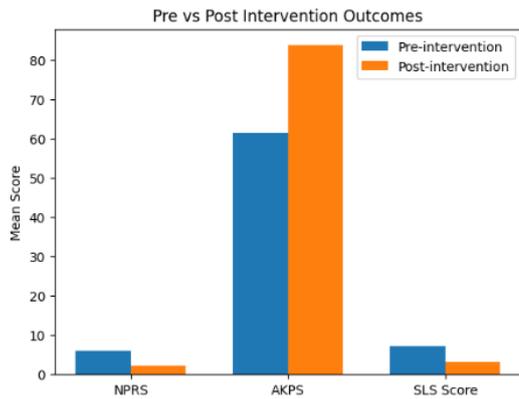
Pain intensity measured using the Numerical Pain Rating Scale (NPRS) showed a significant reduction following the intervention. The mean NPRS score decreased from 6.1 ± 1.2 at baseline to 2.3 ± 1.1 post-intervention, indicating a clinically meaningful reduction in anterior knee pain ($p < 0.001$).

Functional outcomes assessed using the Kujala Anterior Knee Pain Scale (AKPS) demonstrated significant improvement after the rehabilitation program. The mean AKPS score increased from 61.4 ± 9.6 pre-intervention to 83.7 ± 8.2 post-intervention, reflecting marked enhancement in knee-related function and activity tolerance ($p < 0.001$).

Movement quality assessed using the Single-Leg Squat (SLS) test also showed significant improvement following the intervention. The mean SLS movement quality score improved from 7.2 ± 1.4 at baseline to 3.1 ± 1.2 post-intervention, indicating better trunk stability, improved pelvic control, and reduced dynamic knee valgus during single-leg functional tasks ($p < 0.001$).

Overall, participants demonstrated reduced pain, improved functional capacity, and enhanced lower-limb movement control following the individualized kinetic-chain–based physiotherapy protocol.

Outcome Measure	Pre-intervention (Mean \pm SD)	Post-intervention (Mean \pm SD)	p-value
NPRS	6.1 ± 1.2	2.3 ± 1.1	<0.001
AKPS	61.4 ± 9.6	83.7 ± 8.2	<0.001
SLS Score	7.2 ± 1.4	3.1 ± 1.2	<0.001



DISCUSSION

The present study demonstrated that an individualized kinetic-chain-based physiotherapy protocol resulted in significant improvements in pain intensity, functional capacity, and movement quality in individuals with patellofemoral pain. Following the six-week intervention, participants showed a clinically meaningful reduction in anterior knee pain, substantial improvement in Kujala Anterior Knee Pain Scale scores, and enhanced movement control during the single-leg squat task (4). These findings support the growing body of evidence that patellofemoral pain is best managed using a holistic rehabilitation approach that addresses proximal and distal contributors along the lower-limb kinetic chain rather than focusing exclusively on local knee impairments.

The significant reduction in pain observed in the present study may be attributed to improved control of femoral motion and reduced patellofemoral joint stress during functional activities. Abnormal hip kinematics, particularly excessive femoral internal rotation and adduction, are known to increase lateral patellofemoral joint contact pressure and contribute to symptom persistence. Improvements in hip abductor and external rotator strength, combined with enhanced trunk stability achieved through the kinetic-chain-based program, likely resulted in more optimal lower-limb alignment and load distribution during weight-bearing tasks. This mechanistic explanation is consistent with contemporary biomechanical models that emphasize the role of proximal control in patellofemoral pain (13).

The observed improvement in functional outcomes, as reflected by higher AKPS scores, indicates enhanced tolerance to activities that typically aggravate patellofemoral pain, such as stair climbing, squatting, and prolonged sitting. Previous studies have reported superior outcomes when hip-focused strengthening and movement retraining are incorporated into rehabilitation programs compared to knee-focused strengthening alone. The present findings further support this approach by demonstrating that individualized, impairment-based exercise prescription can lead to meaningful functional gains within a relatively short intervention period.

Improvement in movement quality during the single-leg squat suggests enhanced neuromuscular control and kinetic-chain coordination. Dynamic knee valgus and poor trunk and pelvic control observed at baseline were substantially reduced following the intervention, indicating successful motor learning and movement retraining (14). The single-leg squat is a clinically relevant task that reflects everyday and sport-specific loading of the patellofemoral joint; therefore, improvements in this task may translate into better movement efficiency and reduced symptom provocation during daily activities. This highlights the value of incorporating functional movement assessment and task-specific retraining into rehabilitation programs for patellofemoral pain (15).

The individualized nature of the intervention likely contributed to the favorable outcomes observed. Rather than applying a standardized exercise protocol to all participants, exercises were tailored based on each individual's specific movement impairments, proximal weakness, and control deficits. This personalized approach aligns with contemporary physiotherapy principles emphasizing patient-specific assessment and targeted intervention, and may enhance adherence and clinical effectiveness (16).

Clinically, the findings of this study support the integration of kinetic-chain assessment and rehabilitation into routine physiotherapy management of patellofemoral pain. Physiotherapists should consider evaluating trunk,

hip, and foot mechanics in addition to local knee factors, and incorporate movement retraining into exercise programs to address faulty loading patterns (10). This approach may not only improve short-term outcomes but also reduce the risk of symptom recurrence by addressing underlying biomechanical contributors.

Despite the positive findings, the absence of a control group limits direct comparison with traditional knee-focused rehabilitation protocols. Furthermore, the relatively short intervention period does not allow conclusions regarding long-term maintenance of improvements or recurrence rates. Future research employing randomized controlled trial designs with longer follow-up periods is warranted to establish the comparative effectiveness and long-term benefits of individualized kinetic-chain-based rehabilitation for patellofemoral pain (8).

CONCLUSION

The individualized kinetic-chain-based physiotherapy protocol significantly reduced pain and improved functional outcomes in individuals with patellofemoral pain. Participants demonstrated clinically meaningful improvements in NPRS and AKPS scores following the six-week intervention. Movement quality during single-leg functional tasks also improved, indicating better neuromuscular control and lower-limb alignment. These findings highlight the importance of addressing proximal and distal contributors rather than focusing solely on the knee. A holistic, impairment-based rehabilitation approach may optimize patellofemoral joint loading and functional recovery. Incorporating kinetic-chain assessment and movement retraining into routine physiotherapy practice is recommended.

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