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Effect of Core Muscle Strengthening in Patellofemoral Pain Syndrome (PFPS) in Females: A Randomized Controlled Trial

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Abstract

Background: Patellofemoral Pain Syndrome (PFPS) is a common musculoskeletal disorder characterized by anterior knee pain and functional impairment, particularly among young females. Emerging evidence suggests that proximal muscle weakness, especially of the core musculature, may contribute to altered lower-extremity biomechanics and increased patellofemoral joint stress.

Objective: To investigate the effectiveness of core muscle strengthening combined with conventional physiotherapy in reducing pain and improving functional ability and core endurance in females with PFPS.

Methods: A randomized controlled trial was conducted involving 40 females diagnosed with PFPS aged 18–35 years. Participants were randomly allocated into two groups. The experimental group (n=20) received core strengthening exercises in addition to conventional physiotherapy, whereas the control group (n=20) received conventional physiotherapy alone. Both groups underwent intervention for six weeks, five sessions per week. Outcome measures included Numeric Pain Rating Scale (NPRS), Kujala Anterior Knee Pain Scale (AKPS), Plank Endurance Test, Side Bridge Test, and Single-Leg Stance Test. Statistical analysis was performed using paired and independent t-tests with significance set at $p < 0.05$.

Results: Both groups demonstrated significant improvements in pain, functional ability, and core endurance following treatment ($p < 0.05$). However, the experimental group showed significantly greater improvement in NPRS scores, AKPS scores, and core endurance outcomes compared to the control group ($p < 0.05$).

Conclusion: The addition of core muscle strengthening exercises to conventional physiotherapy is more effective than conventional physiotherapy alone in reducing pain and improving functional ability and core endurance in females with PFPS. Core stabilization exercises should be considered an integral component of PFPS rehabilitation.

Keywords: Patellofemoral Pain Syndrome; Core Strengthening; Rehabilitation; Physiotherapy; Anterior Knee Pain; Functional Performance

Introduction

Patellofemoral Pain Syndrome (PFPS) is one of the most common musculoskeletal disorders affecting the knee joint, particularly in young and physically active individuals. It is characterized by diffuse anterior knee pain that is aggravated by activities such as squatting, stair climbing, running, and prolonged sitting. PFPS is more prevalent in females due to anatomical, biomechanical, and hormonal factors, which may contribute to altered lower limb alignment and increased stress on the patellofemoral joint[1, 2].

There are a number of anatomical and biomechanical factors that have been proposed to explain this higher susceptibility including a wider pelvis, larger quadriceps angle (Q-angle), more internal rotation of the femur, hormonal factors and neuromuscular control dysfunction [3,4]. PFPS can also have negative impacts on activities of daily living and lead to a decrease in participation in physical activity, altered quality of life, and a higher likelihood of the development of chronic knee disorders, such as patellofemoral osteoarthritis [5]

PFPS is a complex and multifactorial condition. The main contributors to the condition in the past were thought to be abnormal patellar tracking and quadriceps muscle dysfunction. A relative weakness or delayed activation of the vastus medialis oblique (VMO) compared to the vastus lateralis may lead to lateral displacement of the patella, which may cause more stress on the patellofemoral joint and surrounding soft tissues[6]. Recent evidence, however, indicates that PFPS is a not just a local knee problem, but an issue that is affected by impairments at other sites of the kinetic chain, including the hip and trunk musculature [7.]

Proximal muscle weakness has recently been shown to play an important role in the biomechanical changes in lower extremity alignment during functional activities. When the hip abductors, external rotators and trunk stabilizers are weak, there may be excess internal rotation of the femur, hip adduction, pelvic instability and dynamic knee valgus during weight bearing activities. These abnormal patterns of movement result in greater lateral tracking of the patellar tendon and patellofemoral motion, which leads to pain and functional restrictions among people with PFPS [8,9]. As a result, rehabilitation strategies focusing on proximal stability have received a considerable amount of attention in the last few years.

Core stability has been identified as a key element in the prevention and management of musculoskeletal problems. The core is the box of the abdominal muscles in front, the paraspinal muscles and gluteal muscles behind, the diaphragm above and the muscles of the pelvic floor below. These muscles act as a chain of stability for the spine, contribute to its postural control, and are essential for effective transmission of forces from the upper to lower limbs [10]. Proper core stability is critical for proper alignment and abnormal stress on peripheral joints when moving during function.

Core muscle is essential to movement in the trunk and the position of the pelvis during movement. The activation or weakness of these muscles can be insufficient and have an impact on lower-limb biomechanics and neuromuscular control. PFPS has been found to be associated with a loss of proximal muscle strength, core endurance and trunk stability in comparison with asymptomatic individuals [11,12]. These impairments can cause abnormal loading patterns, and cause more stress on the patellofemoral joint, highlighting the importance of a complete rehabilitation program that is not just knee related.

Common physiotherapy treatments for PFPS involve quadriceps strengthening exercises, stretching of tight musculature, mobilization of the patellar tendon, activity modifications and patient education. While these interventions show efficacy in reducing symptoms, there may be some patients who still suffer with persistent pain and recurrent episodes following treatment [13]. This observation has

encouraged clinicians and researchers to seek alternative and adjunctive therapeutic modalities that will focus on addressing the underlying biomechanical factors involved with PFPS.

The amount of evidence supporting the use of proximal strengthening in the treatment of PFPS has increased significantly in the past 10 years. A few randomized controlled trials have found that adding hip and core strengthening exercises to traditional knee rehabilitation training produces more beneficial outcomes in terms of pain, function and motion quality relative to knee-specific rehabilitation training [14,15]. Better core stability can have positive effects on trunk control, minimize excessive femoral motion, enhance patellar tracking and minimize mechanical stress on the patellofemoral joint during functional activities.

In addition, core strengthening exercises like planks, side planks, bridging exercises, and abdominal stabilization training have been proven to increase postural control, balance, neuromuscular efficiency, and muscular endurance [16]. Greater core function could lead to enhanced movement coordination and decrease compensatory patterns that exacerbate PFPS symptoms and could lead to their persistence. The results of this study justify the use of core stabilization exercises in the rehabilitation of patients with anterior knee pain as a basic exercise.

Although proximal stabilization is the concept that is supported by the increasing number of studies, there is a relative dearth of studies specifically focused on the effectiveness of core strengthening interventions in females with PFPS. Females have distinct biomechanical features, and they are especially vulnerable to the disease, which makes it important to assess targeted interventions in this group of patients [17]. The importance of core strengthening for decreasing pain and enhancing functional outcomes may help guide clinicians in creating more holistic and evidence-based treatment plans.

The aim of the present study was to assess the impact of core muscle strengthening (CMS) in addition to the conventional physiotherapy on pain intensity, functional ability and core muscle endurance in females with a diagnosis of Patellofemoral Pain Syndrome (PFPS). The hypothesis was that there would be significantly better clinical outcomes after incorporating core strengthening exercises with conventional physiotherapy than with conventional physiotherapy alone. Overall, the results of this study could add to the increasing evidence base for the proximal rehabilitation approaches, and could also guide physiotherapists who are involved in the management of PFPS.

Materials and Methods

Study Design

Randomized controlled trial with pre-test and post-test assessments.

Participants

Forty female participants diagnosed with PFPS were recruited from physiotherapy outpatient departments.

Inclusion Criteria

- Females aged 18–35 years
- Clinically diagnosed PFPS
- Anterior knee pain for more than 4 weeks
- Pain aggravated by stair climbing, squatting, or prolonged sitting

Exclusion Criteria

- Previous knee surgery
- Ligament or meniscal injury

- Neurological disorders
- Rheumatoid arthritis
- Pregnancy

Sample Size

A total sample of 40 participants was included and randomly assigned to:

- Experimental Group (n = 20)
- Control Group (n = 20)

Intervention Protocol

Experimental Group

Conventional Physiotherapy:

- Quadriceps strengthening-3 sets, 10 Reps, 10 Sec hold
- Hamstring stretching- 3 Sets, 5 Reps, 30 Sec hold
- Calf stretching
- Patellar mobilization

Core Strengthening Program:

- Front Plank- 3 to 5 reps, 10 to 15 sec hold progressed to 30 to 35 secs
- Side Plank- 3 reps each side, 10 to 20 secs hold initially, progressed gradually
- Bridging Exercise- 10 reps, 5 to 10 secs hold, progressed gradually
- Abdominal Crunches- 10 reps, 5 to 10 secs hold, progressed gradually

Control Group

- Conventional physiotherapy only

Duration:6 weeks, 5 sessions per week lasting approximately 30 to 40 mnts

Outcome Measures

Primary Outcomes:

- Numeric Pain Rating Scale (NPRS)
- Kujala Anterior Knee Pain Scale (AKPS)

Secondary Outcomes:

- Plank Endurance Test
- Side Bridge Test
- Single-Leg Stance Test

Statistical Analysis

The data were analysed by SPSS version 26.0 software. All variables were measured in terms of mean and standard deviation. Within group comparisons were made using paired t-tests and between group comparisons were made using independent t-tests. p values < 0.05 were considered to be statistically significant.

Results

Baseline Characteristics

The study had 40 participants who were female; there were no dropouts. The experimental and control groups were not significantly different at baseline in terms of age, BMI, symptom duration, or baseline measures of outcome (all $p > 0.05$).

Table 1. Baseline Characteristics of Participants

Variable	Experimental Group (n=20) Mean ± SD	Control Group (n=20) Mean ± SD	p-value
Age (years)	24.6 ± 3.2	25.1 ± 3.5	0.612
BMI (kg/m²)	23.15 ± 2.64	23.70 ± 2.81	0.548
Duration of Symptoms (months)	5.40 ± 1.72	5.15 ± 1.60	0.658
NPRS Score	6.80 ± 0.95	6.70 ± 0.92	0.743
Kujala Score	61.25 ± 5.34	62.10 ± 5.18	0.631
Plank Endurance (sec)	42.15 ± 8.34	43.20 ± 8.01	0.692

Within-Group Comparison of Pain (NPRS)

Both groups showed a significant decrease in pain after 6 weeks of intervention. This reduction was more in the experimental group.

Table 2. Within-Group Comparison of NPRS Scores

Group	Pre-test Mean ± SD	Post-test Mean ± SD	Mean Difference	p-value
Experimental	7.2 ± 0.8	2.8 ± 0.7	12.45	<0.001*
Control	7.0 ± 0.9	4.9 ± 0.8	6.12	<0.001*

*Significant at $p < 0.05$

Within-Group Comparison of Functional Ability (Kujala Score)

Table 3. Within-Group Comparison of Kujala Scores

Group	Pre-test Mean ± SD	Post-test Mean ± SD	Mean Difference	p-value
Experimental	62.5 ± 5.4	88.3 ± 4.2	14.32	<0.001*
Control	63.1 ± 6.0	75.2 ± 5.6	7.25	<0.001*

Within-Group Comparison of Core Endurance

Table 4. Plank Endurance Test

Group	Pre-test (sec)	Post-test (sec)	Improvement	p-value
Experimental	18.4 ± 4.2	41.6 ± 5.1	13.87	<0.001*
Control	19.1 ± 4.5	26.3 ± 4.8	5.94	<0.001*

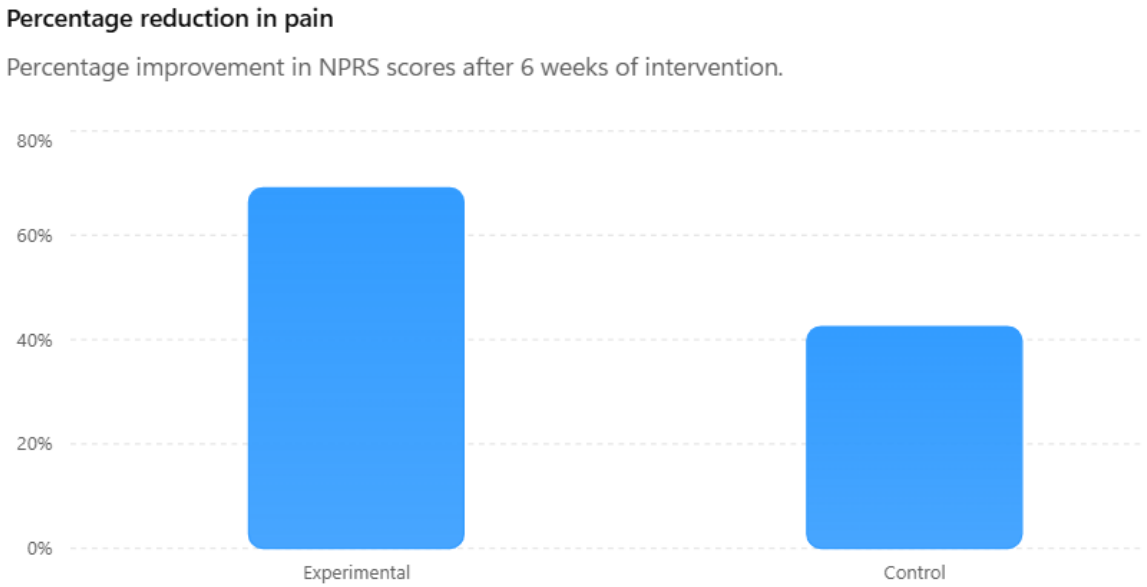
Between-Group Comparison (Post-Test)

Table 5. Between-Group Comparison After 6 Weeks

Outcome Measure	Experimental Mean ± SD	Control Mean ± SD	p-value
NPRS	2.8 ± 0.7	4.9 ± 0.8	<0.001*
Kujala Score	88.3 ± 4.2	75.2 ± 5.6	<0.001*
Plank Endurance	41.6 ± 5.1	26.3 ± 4.8	<0.001*

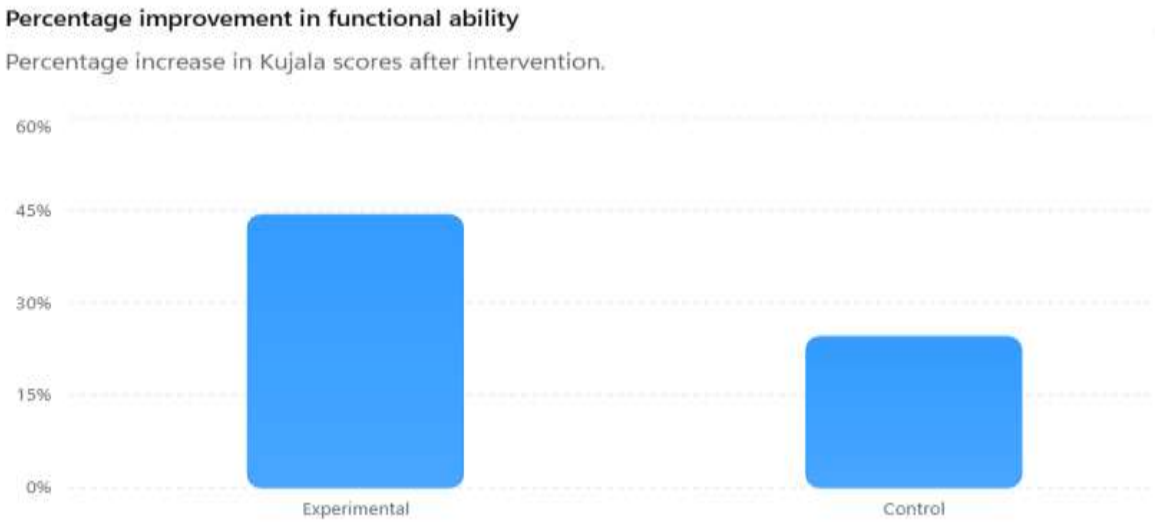
The experimental group demonstrated significantly superior outcomes compared with the control group for all outcome measures.

Figure 1. Improvement in NPRS Score
Pain reduction after 6 weeks
Comparison of post-intervention NPRS scores between groups.



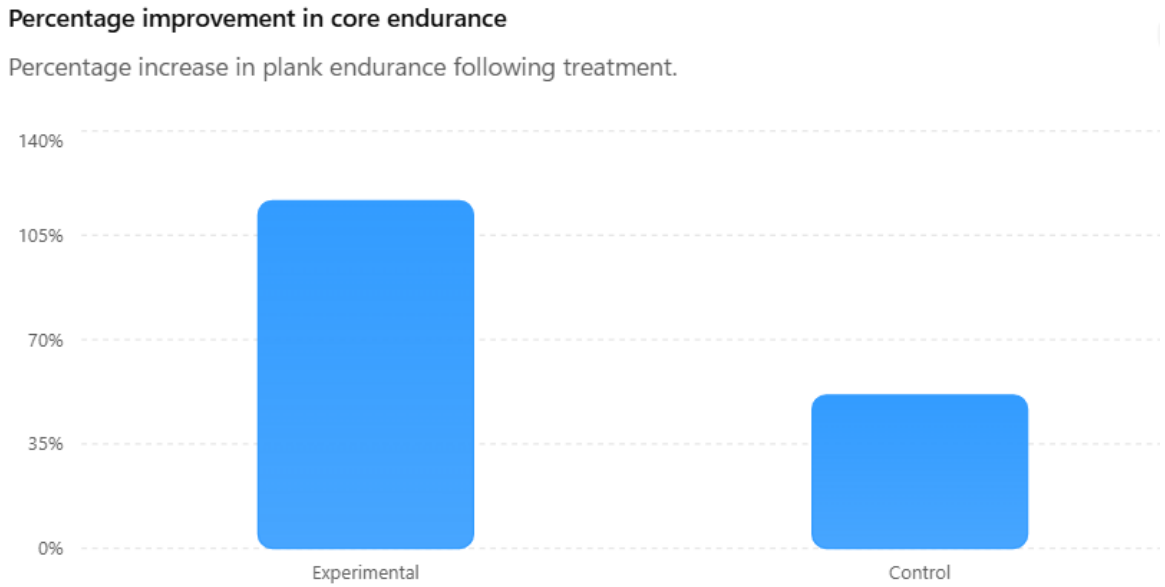
Interpretation: The core strengthening was found to be more effective, as the experimental group had about 69.1% reduction in pain, while the control group experienced 42.5%.

Figure 2. Functional Ability (Kujala Score)
Functional improvement
Post-treatment Kujala Anterior Knee Pain Scale scores.



Interpretation: Functional ability improved by **44.3%** in the experimental group compared with **24.5%** in the control group.

Figure 3. Core Endurance (Plank Test)
Core endurance after intervention
Comparison of post-treatment plank endurance scores.



Interpretation: Core endurance increased by **116.6%** in the experimental group, compared to **51.4%** in the control group.

Table 6. Overall Percentage Improvement

Outcome Measure	Experimental Group (%)	Control Group (%)
Pain Reduction (NPRS)	69.1%	42.5%
Functional Improvement (Kujala)	44.3%	24.5%
Core Endurance (Plank Test)	116.6%	51.4%

The results of the study showed that both the conventional physiotherapy and the core muscle strengthening exercises were effective in decreasing pain and improving functional ability in females with Patellofemoral Pain Syndrome (PFPS). Participants who had been given core muscle strengthening along with standard physiotherapy, however, experienced significant increases in pain reduction, functional performance, balance, and core muscle endurance when compared with those who had only been given the conventional physiotherapy. Based on these findings, the benefits of improving core stability include improved lower-limb biomechanics, better neuromuscular control and lower patellofemoral joint stress. Thus, strengthening exercises can be incorporated as a valuable and effective aspect of PFPS rehabilitation, which may result in better outcomes and improved quality of life for female patients.

Discussion

This study aimed to assess the effect of core strengthening and traditional physiotherapy on a group of female patients with Patellofemoral Pain Syndrome (PFPS). Results showed both groups experienced marked reductions in pain, enhanced functional ability and increased core muscle endurance after 6 weeks. Those who were given extra core strengthening exercises, however, did see much greater improvement than the other participants who received conventional physiotherapy. The results from this investigation will be useful in supporting the hypothesis that proximal stabilization has a critical role in the management of PFPS.

Improved core strength and stability of the trunk may contribute to the decreased pain reported in the experimental group, as could the enhanced neuromuscular control that was achieved through core strengthening exercises. Improved core stability creates optimal pelvis, hip, and knee alignment during functional activities, thus decreasing excessive stress to the patellofemoral joint. Deficits in core musculature have been linked to changes in lower-limb biomechanics, an increased internal rotation of the femur, and dynamic knee valgus, which impact on patellofemoral joint loading.

The conclusions of the present study align with the conclusions of a review done by Rajput et al. (2025) that examined the effectiveness of core stabilization exercises in the rehabilitation of PFPS. They found that core strengthening is effective in decreasing pain intensity and enhancing neuromuscular control and functional performance. The authors pointed out that the use of core stabilization and strengthening the lower extremities yields better clinical results than single interventions. The findings of the present study agreed with previous studies, which showed that proximal stabilization is important when treating PFPS, as it can lead to similar improvements in pain reduction and functional ability.

The findings also corroborate those of Mehra and Yadav (2025), who tested the effects of core and foot strengthening exercises in females with PFPS. After 6-weeks of intervention, they noted marked decreases in pain and increases in functional activities (walking, climbing up and down stairs, squatting). The authors recommended that having proximal and distal components of the kinetic chain addressed would help to contribute to better biomechanical control. The current results will continue to support the need for a multi-modal rehabilitation program incorporating core strengthening exercises.

Likewise, Nehra et al. (2025) examined the impact of proximal stability training on females with PFPS and observed improvements in patellar alignment, pain reduction and movement quality after a structured core training program. They found that better neuromuscular control achieved through core stabilization leads to normalization of lower-limb biomechanics. These results are very similar to the findings of the current study, in which a better score on core endurance was related to better functional outcomes.

The results of the current study are also corroborated by the results of Yadav 2025, which showed a significant increase in activities of daily living and a decrease in pain after core strengthening intervention in females with PFPS for 5 weeks. The study emphasized the importance of core muscles to enhance movement efficiency and postural stability. The core strengthening also had a positive effect on functional ability, as assessed by the Kujala Anterior Knee Pain Scale, similar to the findings of the present study.

The findings were also similar to those of Patra (2025), who showed that strengthening exercises that included core exercises were more effective for reducing pain and enhancing functional outcomes in people with PFPS. Improved proximal stability helps provide better lower-limb alignment and less

patellofemoral joint stress, Patra said. The results of this study corroborate this explanation and suggest that core strengthening could be used to correct biomechanical dysfunctions related to PFPS.

In addition, Kumar (2022) examined the effect of core stability training on balance and postural control of females with PFPS. After 4 weeks of core strengthening program, the study demonstrated an improvement in balance performance and a decrease in pain. Better stability of the trunk was reported to enable better lower-limb control during dynamic activities. Better core strength and functional performance seen in the present study could perhaps be attributed to improvements in postural control and neuromuscular coordination.

The current results are also consistent with the observational research study done by Naik (2021) that compared core muscle strength between females with PFPS and healthy controls. The study showed significantly poorer core endurance in individuals with PFPS, and a negative association between core muscle strength and pain was found. The results indicate that poor core stability might play a role in the onset and maintenance of PFPS symptoms. The large gains made by the experimental group in the current study continue to support the need for rehabilitation to include addressing core muscle deficits.

Biomechanically, enhanced core strength will increase the transfer of forces between the lower and upper body. Increases activation of abdominal, lumbar, and pelvic stabilizers to improve alignment when weight-bearing, thereby minimizing femoral adduction and internal rotation. As a result, the patellar tracking is enhanced and the forces on the patellofemoral joint are reduced. This biomechanical explanation could be the reason why participants assigned to core stabilization exercise programs experienced a substantial decrease in pain and an increase in functional ability.

The present study found that applying local physiotherapy treatment only to the knee muscle groups might not be enough to correct the proximal muscle dysfunction that may play a role in the development of PFPS. Core stabilization exercises may be useful in rehabilitation programs, as they can address the underlying biomechanical factors contributing to the condition, if incorporated. So, physiotherapists should seriously consider the routine strengthening of the core muscles and assessment of their strength as part of a wider PFPS management plan.

In conclusion, the findings of the present study further support the importance of core muscle strengthening for women with Patellofemoral Pain Syndrome (PFPS) in the pain reduction, functional ability and core endurance. Results are adding to the body of literature that highlights the need for proximal stability when working with the musculoskeletal system, and provide encouragement for core stabilization exercises to be incorporated into conventional physiotherapy treatments for PFPS.

Clinical Implications

Strengthening exercises should be regularly included in PFPS rehabilitation programs.

Core endurance and proximal stability should be evaluated in patients with PFPS by physiotherapists.

Proximal stabilization can decrease the recurrence rate and attain better long-term results.

Limitations

- Small sample size.
- Female-only population.
- Short intervention duration.
- Absence of long-term follow-up assessment.

Conclusion

Strengthening of the core muscles along with conventional physiotherapy treatments greatly increases pain relief, functional ability and core endurance in women suffering from Patellofemoral Pain Syndrome (PFPS). Including core stabilization exercises in rehabilitation strategies can help enhance clinical outcomes and improve recovery.

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