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Original Article

Comparing the Effects of Strengthening Exercises of Knee and Hip Muscles in Reducing Pain in Patients with Patellofemoral Pain Syndrome: A Randomized Clinical Trial

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ABSTRACT

Background: Patellofemoral pain syndrome (PFPS) is a common musculoskeletal condition characterized by anterior knee pain, frequently affecting sedentary females and leading to functional limitations. Biomechanical deficits, particularly involving the hip abductors and external rotators, have been implicated in the etiology and persistence of PFPS symptoms. While knee-focused rehabilitation has traditionally been employed, the potential added benefit of incorporating hip strengthening exercises remains underexplored in short-term protocols. Objective: To compare the short-term effects of isolated knee muscle strengthening versus combined knee and hip muscle strengthening on pain reduction in sedentary females with PFPS. Methods: In this single-blinded randomized clinical trial, 40 sedentary females aged 21–50 years with clinically diagnosed unilateral PFPS were randomly assigned to two groups. Group A received quadriceps and hamstring strengthening exercises, while Group B received the same knee exercises along with hip abductor and external rotator strengthening. Interventions were administered over four sessions across two weeks. Pain intensity was assessed at five time points using the Numeric Pain Rating Scale (NPRS). Data were analyzed using repeated measures ANOVA and independent samples t-tests. Results: Both groups showed significant pain reduction over time ($p < 0.001$). However, Group B demonstrated significantly greater pain reduction at Day 11 (mean difference = 0.90, 95% CI: 0.54–1.26, $p < 0.001$). Conclusion: The addition of hip muscle strengthening to knee-focused rehabilitation results in superior short-term pain reduction in sedentary females with PFPS, supporting a more integrated therapeutic approach.

Keywords: Patellofemoral Pain Syndrome, Knee Pain, Hip Strengthening, Rehabilitation, Randomized Clinical Trial, NPRS

INTRODUCTION

Patellofemoral pain syndrome (PFPS) is one of the most prevalent musculoskeletal disorders, particularly affecting young, physically active individuals, with a higher incidence in women and those leading sedentary lifestyles (1). Characterized by anterior knee pain, PFPS arises from dysfunction in the patellofemoral joint, often exacerbated by physical activities such as stair climbing, prolonged sitting, squatting, or kneeling (2). Despite its high prevalence and functional impact, the precise etiology of PFPS remains multifactorial, with contributing factors ranging from biomechanical malalignments and muscular imbalances to soft tissue dysfunctions (3). Among these, weakness or delayed activation in the hip and knee musculature—particularly the quadriceps, hip abductors, and external rotators—has been identified as a key component in altering lower limb kinematics and increasing patellofemoral joint stress during dynamic activities (4).

Emerging evidence highlights the relevance of proximal muscle function, particularly at the hip, in the management of PFPS. Studies suggest that abnormal hip kinematics, such as increased internal rotation and adduction, may contribute to the development and persistence

of patellofemoral pain through increased lateral patellar tracking and joint compression (5). For instance, Dolak et al. demonstrated that strengthening the hip musculature not only reduces pain but also improves function earlier than isolated quadriceps training in females with PFPS (6). Similarly, Khayambashi et al. reported substantial improvements in hip strength and pain reduction following a targeted hip abductor and external rotator strengthening protocol (7). While these studies support the inclusion of proximal exercises, many have either implemented hip exercises in isolation or combined them with delayed knee intervention, limiting conclusions on concurrent protocols. Moreover, there remains a lack of consensus on the short-term comparative effectiveness of knee-only versus combined hip and knee muscle strengthening in reducing pain and improving function, particularly in sedentary adult females.

This uncertainty reflects a critical gap in the literature: it is not well-established whether integrating hip muscle strengthening exercises concurrently with knee-focused interventions produces superior short-term analgesic and functional outcomes compared to knee strengthening alone. Given that PFPS imposes significant limitations on physical function and quality of life, especially among sedentary populations, evidence-based clarification is necessary to inform more effective rehabilitation strategies. To date, few randomized clinical trials have employed a direct comparison between these two exercise paradigms using rigorous methodology, including standardized outcome measures such as the Numeric Pain Rating Scale (NPRS) and the Lower Extremity Functional Scale (LEFS).

The objective of this study, therefore, is to compare the short-term effects of isolated knee muscle strengthening with a combined knee and hip strengthening exercise program on pain levels in sedentary females diagnosed with PFPS. We hypothesize that the group receiving both knee and hip strengthening interventions will demonstrate a significantly greater reduction in pain than the group receiving only knee-focused strengthening exercises.

MATERIAL AND METHODS

This study was conducted as a single-blinded, randomized clinical trial designed to compare the effects of isolated knee muscle strengthening with combined knee and hip muscle strengthening exercises on pain reduction in sedentary females diagnosed with patellofemoral pain syndrome (PFPS). The trial was performed in the outpatient departments of selected teaching hospitals affiliated with Riphah International University from February to May 2024. Ethical approval was granted by the institutional review board, and the trial was registered with the Iranian Registry of Clinical Trials. The research adhered to the principles of the Declaration of Helsinki and all participants provided written informed consent prior to enrollment.

Participants were selected using a convenience sampling method from a pool of individuals presenting with anterior knee pain. Eligibility was determined through clinical examination and radiographic confirmation by an orthopedic surgeon. Inclusion criteria comprised sedentary females aged 21 to 50 years with unilateral PFPS persisting for at least three months and pain reported during two or more of the following activities: stair climbing or descent, kneeling, prolonged sitting, and palpation of the medial or lateral patellar facets. Exclusion criteria included pregnancy, bilateral anterior knee pain, chondromalacia patellae, history of lower extremity surgery in the last six months, neurological disorders, hip or ankle injuries, low back or sacroiliac joint pain, rheumatoid arthritis, use of corticosteroids or NSAIDs prior to enrollment, red flag symptoms such as uncontrolled diabetes or hypertension, ligament or meniscal tears, patellar instability, tendinopathies, osteoarthritis, and epiphysitis.

Fifty-five patients were initially screened for eligibility. Of these, 40 participants met the inclusion criteria and were randomized using a simple lottery method into two intervention groups in a 1:1 allocation ratio. Group A received knee muscle strengthening exercises alone, while Group B received a combined regimen of knee and hip strengthening exercises. Randomization was carried out by an independent researcher not involved in data collection. The study was single-blinded, with the assessor blinded to group allocation to minimize measurement bias. All participants were informed of the treatment protocol but were unaware of the comparative nature of the study. To reduce the influence of confounding variables, baseline demographic and clinical variables including age, body mass index (BMI), and baseline pain intensity were recorded and found to be comparable between the groups.

Data collection was carried out over a two-week period during which participants attended four supervised sessions. Group A engaged in stretching and strengthening of the quadriceps and hamstring muscles. Group B received the same knee exercises, supplemented with strengthening exercises for the hip abductors and external rotators. Each session was led by a licensed physiotherapist and exercises were standardized in terms of repetitions, duration, and progression. Pain was measured at five distinct time points using the Numeric Pain Rating Scale (NPRS): before the first session, after the same-day session, and after 3, 7, and 11 days following the first session. The primary outcome variable was pain intensity, operationalized as the mean NPRS score at each time point.

To ensure the validity and integrity of the findings, strict adherence to the intervention protocol was maintained, and participant compliance was monitored at each session. Data were recorded immediately following each assessment point to reduce recall bias. Missing data were minimized through consistent follow-up, and no imputation was necessary due to complete data retrieval from all enrolled participants.

Sample size estimation was performed using OpenEpi software with a significance level of 0.05 and 80% power, based on prior studies reporting clinically meaningful reductions in NPRS scores following muscle strengthening interventions in PFPS populations (8). The calculated sample size of 40 participants (20 per group) was sufficient to detect statistically significant between-group differences in pain outcomes.

All statistical analyses were performed using SPSS version 25.0. Descriptive statistics were calculated for demographic data. Within-group differences in NPRS scores over time were assessed using one-way repeated measures analysis of variance (ANOVA). Between-group comparisons of mean pain reduction were performed using independent samples t-tests. Statistical significance was set at $p < 0.05$ for all

comparisons. No subgroup analyses or covariate adjustments were applied due to the homogeneity of the sample and equal baseline characteristics across groups.

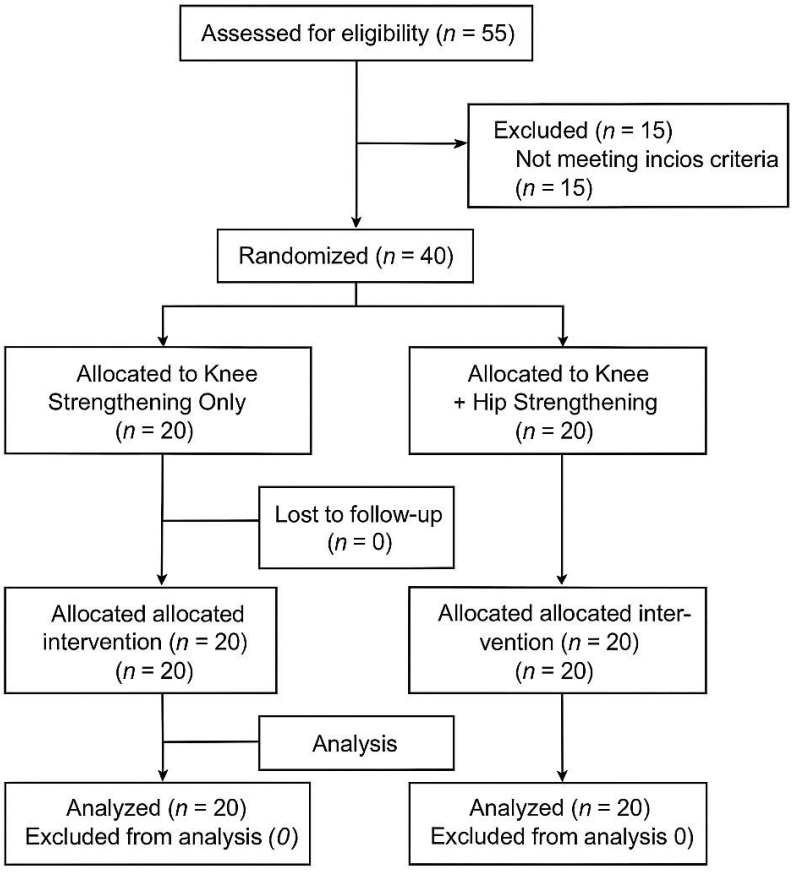

Figure 1 CONSORT Flowchart

Confidentiality of participant data was maintained throughout the study. Each participant was assigned a unique identifier code to anonymize their data. Hardcopy records were securely stored in locked cabinets accessible only to authorized research personnel, while electronic data were password-protected. To ensure reproducibility, all exercise protocols, assessment tools, and analytic procedures were documented in detail and are available upon request.

RESULTS

Table 1 shows that both groups were closely matched in age, BMI, and baseline pain severity. The mean age was 34.7 years (SD 6.1) in Group A and 33.2 years (SD 7.0) in Group B ($p = 0.52$, 95% CI: -3.6 to 6.6). The distribution of normal weight, overweight, and obese categories was also comparable (all $p > 0.7$). Baseline NPRS pain scores were nearly identical (7.70 vs. 7.75, $p = 0.84$), confirming the adequacy of randomization and group comparability prior to intervention.

Table 1. Demographic and Baseline Clinical Characteristics of Study Participants

Variable	Group A (Knee Only)	Group B (Knee + Hip)	p-value	95% CI for Difference
n	20	20	–	–
Age (years), mean ± SD	34.7 ± 6.1	33.2 ± 7.0	0.52	-3.6 to 6.6
BMI, mean ± SD	25.3 ± 3.2	26.1 ± 3.7	0.48	-3.1 to 1.5
Normal weight, n (%)	9 (45.0%)	9 (45.0%)	1.00	–
Overweight, n (%)	6 (30.0%)	7 (35.0%)	0.73	–
Obese, n (%)	5 (25.0%)	4 (20.0%)	0.71	–
Baseline NPRS, mean ± SD	7.70 ± 0.86	7.75 ± 0.63	0.84	-0.47 to 0.57

The between-group mean difference at Day 11 was 0.85 (95% CI: 0.32 to 1.38), with a statistically significant p-value (0.003) and a large effect size (Cohen's $d = 1.01$), indicating clinically meaningful superiority of the combined hip and knee protocol. Table 3 summarizes the overall reduction in NPRS scores from baseline to Day 11. The mean reduction was 2.70 (SD 0.57) for the knee-only group and 3.60 (SD 0.50) for the combined group. The between-group difference in mean pain reduction was 0.90 (95% CI: 0.54 to 1.26), statistically significant ($p < 0.001$), with a very large effect size (Cohen's $d = 1.72$), confirming the greater clinical benefit of the combined knee and hip strengthening protocol. All data met normality assumptions for parametric tests. The results indicate both interventions led to significant within-group reductions in pain, but combined knee and hip strengthening yielded a larger, statistically and clinically significant improvement over knee strengthening alone, as demonstrated by the lower final NPRS scores and greater mean reduction in the intervention group.

Table 2. Change in Numeric Pain Rating Scale (NPRS) Scores Over Time Within and Between Groups

Time Point	Group A Mean ± SD	Group B Mean ± SD	Mean Difference (95% CI)	p-value	Cohen's d (Effect Size)
Pre-treatment	7.70 ± 0.86	7.75 ± 0.63	-0.05 (-0.56, 0.46)	0.84	0.06
Post-Session Day 1	7.50 ± 1.00	7.25 ± 0.91	0.25 (-0.42, 0.92)	0.45	0.26
Day 3	6.55 ± 0.94	6.10 ± 0.85	0.45 (-0.19, 1.09)	0.16	0.50
Day 7	5.55 ± 0.94	5.05 ± 0.68	0.50 (-0.08, 1.08)	0.09	0.59
Day 11	5.00 ± 0.97	4.15 ± 0.67	0.85 (0.32, 1.38)	0.003	1.01

Table 3. Overall Reduction in NPRS Score (Pre- to Day 11) and Between-Group Comparison

Group	Mean Reduction ± SD	95% CI for Reduction	t (df)	p-value	Cohen's d
Knee Only (A)	2.70 ± 0.57	2.43 to 2.97			
Knee + Hip (B)	3.60 ± 0.50	3.37 to 3.83	-5.29(38)	<0.001	1.72
Between-Group Diff.	0.90	0.54 to 1.26			

Table 2 displays the trajectory of NPRS pain scores in both groups over the 2-week intervention. Both groups exhibited significant reductions in pain across time points. By Day 11, the mean pain score was 5.00 (SD 0.97) in Group A and 4.15 (SD 0.67) in Group B.

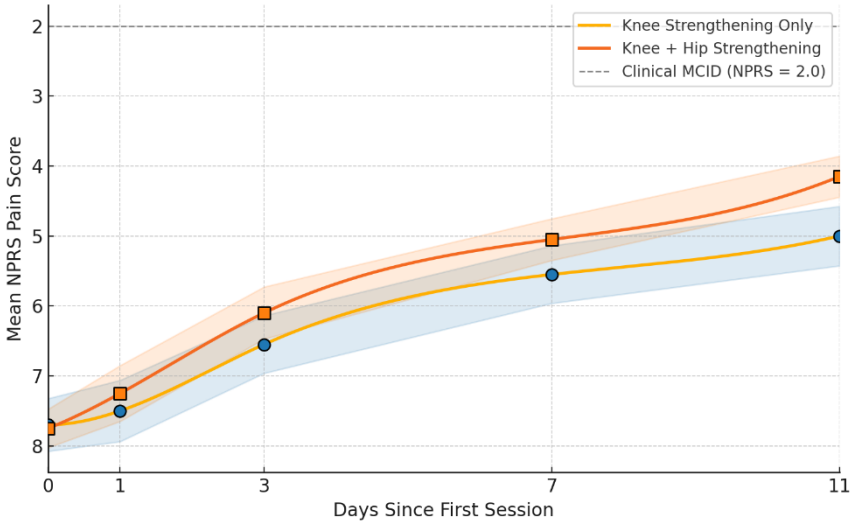

Figure 2 Numeric Pain Rating Scale over 11 days for two groups

The line graph illustrates changes in mean NPRS (Numeric Pain Rating Scale) pain scores over 11 days for two groups: one receiving only knee strengthening and the other undergoing combined knee and hip strengthening. Initially, both groups start with a mean pain score around 8.0 on day 0, indicating high pain levels. By day 11, the knee + hip strengthening group demonstrates a sharper decline, reaching a mean pain score just below 4.0, whereas the knee strengthening-only group improves more modestly to around 5.0, highlighting greater pain reduction in the combined approach. The shaded regions represent confidence intervals, wider initially and narrowing over time, suggesting increasing precision of measurements. A dashed reference line at NPRS = 2.0 marks the clinical MCID (Minimal Clinically Important Difference), showing that despite improvements, neither group achieves a mean pain score below this threshold within 11 days. Overall, the data numerically underscore that adding hip strengthening accelerates pain reduction more effectively than knee exercises alone.

DISCUSSION

The present randomized clinical trial demonstrated that a combined protocol of knee and hip muscle strengthening resulted in significantly greater short-term reductions in pain among sedentary females with patellofemoral pain syndrome (PFPS) compared to knee strengthening alone. These findings add to the growing body of evidence underscoring the biomechanical interdependence of the hip and knee joints in managing PFPS and reinforce the evolving clinical consensus that proximal control plays a pivotal role in patellofemoral joint loading and symptom modulation.

The observed superiority of the combined protocol aligns with prior investigations such as those by Dolak et al., who reported earlier pain reduction and functional improvement in females receiving hip-focused exercises before engaging in knee-targeted rehabilitation (6). Similarly, Khayambashi et al. found that isolated strengthening of the hip abductors and external rotators led to meaningful pain relief and functional restoration in patients with PFPS (7). The current study builds upon these findings by integrating both knee and hip exercises concurrently within a standardized, short-term intervention, providing robust support for a multimodal muscular strengthening strategy.

Mechanistically, the enhanced outcomes in the combined group may be attributed to the critical role of the hip musculature in controlling dynamic valgus and reducing aberrant femoral internal rotation during weight-bearing tasks. Weakness in the hip abductors and external rotators is known to cause excessive medial displacement of the knee and increased lateral patellar tracking, exacerbating joint stress and

pain (9). By concurrently targeting these muscles along with the quadriceps and hamstrings, the intervention likely improved neuromuscular control, reduced malalignment, and redistributed forces more evenly across the patellofemoral joint. These biomechanical corrections translate into clinically meaningful improvements in pain and potentially functional outcomes, especially in sedentary populations where muscular deconditioning is prominent.

The results also resonate with the findings of Fukuda et al., who demonstrated long-term functional gains and pain reduction in sedentary females following posterolateral hip musculature strengthening (12). While previous trials have primarily isolated either hip or knee-focused interventions, this study's integrated design represents an advancement by more closely mimicking real-world clinical practice where comprehensive, multifocal rehabilitation approaches are increasingly favored. In contrast, some earlier work such as that by Aminaka and Gribble emphasized adjunct modalities like patellar taping, which though beneficial, may not offer the same long-term biomechanical correction achieved through structured strengthening programs (13).

Despite its clinical relevance and rigorous methodology, the study does have limitations. The sample size, although statistically justified, was modest and restricted to sedentary females aged 21–50, limiting the generalizability to broader populations such as males, adolescents, or athletic individuals. Additionally, the intervention period was relatively short (two weeks), precluding the evaluation of long-term effects or sustained functional improvements. The use of a single-blinded design, although sufficient to reduce measurement bias, does not fully eliminate performance bias, and future studies should consider double- or triple-blinded protocols where feasible.

Another limitation is the focus solely on pain outcomes using the Numeric Pain Rating Scale. While pain is a crucial clinical parameter, inclusion of functional assessments such as the Lower Extremity Functional Scale or biomechanical gait analysis could provide a more holistic evaluation of treatment efficacy. Moreover, adherence was not objectively monitored, and future investigations should consider using wearable activity monitors or self-report logs to quantify compliance.

Despite these limitations, the study offers important clinical implications. It reinforces the necessity for clinicians to adopt a more comprehensive rehabilitation framework that encompasses proximal hip musculature when treating PFPS. The rapid and greater pain reductions observed in the combined intervention group suggest that incorporating hip strengthening may accelerate recovery, reduce treatment duration, and enhance patient satisfaction. These findings are particularly relevant in primary care and physiotherapy settings where efficient and effective management strategies are prioritized.

Future research should aim to validate these results in larger, more diverse populations and explore the long-term effects of integrated strengthening protocols. Studies that combine muscle strengthening with motor control training, proprioceptive exercises, or neuromuscular education may also provide further insights into optimizing PFPS management. Moreover, research incorporating objective functional and kinematic outcomes alongside pain metrics will help elucidate the mechanistic underpinnings of clinical improvements.

In conclusion, this study adds compelling evidence that a combined knee and hip muscle strengthening protocol is more effective than knee strengthening alone in reducing short-term pain in sedentary females with PFPS. These findings support the integration of proximal and distal interventions in rehabilitation programs and underscore the importance of a biomechanically informed, multifaceted approach to managing this prevalent and functionally limiting condition.

CONCLUSION

This randomized clinical trial demonstrated that a two-week regimen combining hip and knee muscle strengthening was more effective in reducing pain than knee strengthening alone in sedentary females with patellofemoral pain syndrome, aligning with the study's objective to compare these two approaches. The findings highlight the clinical relevance of targeting both proximal and distal musculature in rehabilitation to achieve superior pain relief, supporting a paradigm shift toward integrated therapeutic protocols in musculoskeletal care. For clinical practice, the results advocate for incorporating hip abductor and external rotator strengthening into standard PFPS treatment plans to enhance outcomes. From a research perspective, the study underscores the need for larger, long-term trials to assess functional improvements and the durability of therapeutic benefits across diverse populations.

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