

EFFECTS OF HIP CORE MUSCLE STRENGTHENING AND KNEE MUSCLES STRENGTHENING EXERCISES ON PAIN, STRENGTH AND FUNCTIONAL DISABILITY AMONG PATIENTS WITH PATELLOFEMORAL PAIN SYNDROME

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Abstract

Background: Patellofemoral Pain Syndrome (PFPS) is a prevalent musculoskeletal disorder characterized by anterior knee pain, impaired muscular strength, and functional limitations. Although both proximal and knee-focused strengthening exercises are commonly incorporated into rehabilitation programs, the comparative effectiveness of hip and core strengthening versus knee strengthening remains clinically relevant.

Objective: To compare the effects of hip and core muscle strengthening exercises with knee muscle strengthening exercises on pain intensity, functional status, and muscle strength among patients with PFPS.

Methodology: A randomized comparative study was conducted among 30 patients aged 20–40 years recruited through purposive sampling from a private clinical setting in Lahore. Participants were randomly allocated into two equal groups. The Hip/Core Strengthening Group (n = 15) received hip and core strengthening exercises, whereas the Knee Strengthening Group (n = 15) received knee strengthening exercises. Both groups additionally received conventional physiotherapy comprising activity modification, postural training, cryotherapy/thermotherapy, transcutaneous electrical nerve stimulation (TENS), and soft-tissue mobilization. Treatment was administered three times per week for 12 weeks. Pain intensity, functional status, and muscle strength were assessed before and after treatment using the Visual Analogue Scale (VAS), Kujala Patellofemoral Questionnaire, and Hand-Held Dynamometry (HHD), respectively. Data were analyzed using SPSS. Paired-samples t-tests, independent-samples t-tests, and the Mann-Whitney U test were applied as appropriate, with statistical significance set at $p < 0.05$.

Results: Both groups demonstrated statistically significant improvements in pain intensity, functional status, and muscle strength following the intervention ($p < 0.001$). Mean VAS scores decreased from 6.18 ± 1.16 to

4.13 $\pm$ 1.25 in the Hip/Core Strengthening Group and from 5.85 $\pm$ 1.00 to 4.41 $\pm$ 1.10 in the Knee Strengthening Group. A statistically significant between-group difference was observed for pain intensity ($p = 0.010$), favoring the Hip/Core Strengthening Group. Kujala scores increased from 55.20 $\pm$ 4.43 to 67.87 $\pm$ 6.42 in the Hip/Core Strengthening Group and from 55.67 $\pm$ 6.06 to 66.60 $\pm$ 6.05 in the Knee Strengthening Group; however, the between-group difference was not statistically significant ($p = 0.268$). HHD-measured muscle strength increased from 21.55 $\pm$ 3.01 to 26.50 $\pm$ 3.20 in the Hip/Core Strengthening Group and from 22.43 $\pm$ 4.10 to 26.51 $\pm$ 4.61 in the Knee Strengthening Group, with no statistically significant between-group difference ($p = 0.061$).

Conclusion: Both hip and core strengthening and knee strengthening exercises, when combined with conventional physiotherapy, significantly improved pain, functional status, and muscle strength in patients with PFPS. However, hip and core strengthening produced a significantly greater reduction in pain intensity, whereas improvements in functional status and muscle strength were comparable between the two groups. Hip and core strengthening may therefore represent a particularly beneficial exercise strategy for reducing pain in individuals with PFPS.

1. INTRODUCTION

Patellofemoral Pain Syndrome (PFPS) is a common musculoskeletal disorder characterized by diffuse anterior knee pain that is typically aggravated by activities involving knee loading and flexion. It is frequently described as anterior knee pain or runner's knee and is generally considered a diagnosis of exclusion because no single structural abnormality consistently explains the clinical presentation [1, 2]. Recent studies from Pakistan have reported a substantial burden of PFPS among physically active and occupational populations, with prevalence estimates ranging from 15.4% among university athletes to approximately 71% among male sanitary workers. Higher body mass index (BMI) and obesity have also been associated with PFPS [3–5].

The patellofemoral joint is influenced by the interaction of local and proximal structures within the lower-limb kinetic chain. Although the quadriceps mechanism and surrounding knee structures contribute to patellar stability, the hip and pelvic musculature plays an important role in controlling femoral alignment and patellar tracking during functional activities [6]. In particular, the gluteus medius and gluteus Maximus regulate hip abduction and external

rotation, thereby contributing to pelvic stability and control of excessive femoral motion [7].

The etiology of PFPS is multifactorial and involves muscular weakness, altered neuromuscular control, biomechanical abnormalities, and excessive mechanical loading. Weakness of the hip and core musculature may contribute to excessive hip adduction and femoral internal rotation, increasing dynamic knee valgus and patellofemoral joint stress [8]. Individuals with PFPS commonly demonstrate altered movement patterns during squatting, stair negotiation, running, and landing, which may further increase patellofemoral loading [2, 4]. Although quadriceps weakness and impaired vastus medialis oblique activation have traditionally been emphasized, contemporary evidence increasingly recognizes proximal muscle weakness as an important contributor to lower-limb malalignment and impaired dynamic control [8].

Clinically, PFPS is associated not only with pain but also with reduced quadriceps and hip muscle strength, impaired muscular endurance, and limitations in functional activities [9]. Symptoms are commonly provoked by stair climbing, squatting, running, kneeling, and prolonged sitting, potentially resulting in persistent

functional restrictions and reduced quality of life [2,7]. Functional assessment may include movement-based tests such as the single-leg squat and step-down test, while muscle strength can be objectively quantified using hand-held dynamometry (HHD) [6].

Physiotherapy is the principal conservative treatment for PFPS, with exercise therapy forming the cornerstone of rehabilitation. Conventional knee-focused programs commonly emphasize quadriceps strengthening through exercises such as straight-leg raises, terminal knee extensions, mini-squats, and closed kinetic chain activities [10]. Although these interventions can improve knee strength and symptoms, they may not adequately address proximal deficits contributing to abnormal lower-limb mechanics [11].

Hip and core strengthening has therefore gained increasing attention as an alternative or complementary rehabilitation strategy. Exercises targeting the gluteal and trunk musculature, including hip abduction, clamshells, bridging, and planks, are intended to improve pelvic stability, regulate femoral motion, and reduce excessive hip adduction and internal rotation [12]. By contrast, knee strengthening primarily targets the quadriceps and surrounding knee musculature to enhance local stability and facilitate optimal patellar control [13]. Both approaches may improve clinical outcomes; however, the relative effectiveness of proximal versus knee-focused strengthening remains clinically relevant.

Therefore, the present study aimed to compare the effects of hip and core muscle strengthening exercises versus knee muscle strengthening exercises on pain, muscle strength, and functional disability among patients with PFPS. The findings may assist physiotherapists in selecting an appropriate strengthening strategy for the rehabilitation of individuals with PFPS.

2. CRITICAL ANALYSIS OF PREVIOUS LITERATURE

Current evidence supports the role of proximal and core musculature in PFPS rehabilitation, although the optimal strengthening strategy remains uncertain. Prieto-Garcia et al. [12], Azab

et al. [17], Raisi et al. [18], and Tazesh et al. [20] reported that core and hip strengthening, particularly when combined with conventional rehabilitation, improved pain, muscle strength, and functional outcomes. However, variations in participant characteristics, intervention duration, exercise protocols, and outcome measures limit direct comparison and generalizability.

Knee-focused strengthening also demonstrates clinical benefits. Mikayla et al. [14] found that VMO-specific strengthening improved pain and patellar alignment, while Wu et al. [15] and Mohamed Kamel et al. [16] reported additional benefits when knee and hip strengthening were combined with whole-body vibration or foot exercises. Conversely, Lee et al. [19] found limited effects on knee strength and hamstring flexibility, despite improvements in muscle activation and clinical outcomes. These findings suggest that PFPS may require a comprehensive approach rather than isolated strengthening of a single muscle group.

The broader evidence appears to favor hip or combined strengthening. Manojlovic et al. [21] reported greater pain reduction with hip-and-knee exercise programs than knee-only interventions (MD = -1.71, 95% CI: -3.11 to -0.30; $p = 0.02$), although substantial heterogeneity ($I^2 = 96\%$) limits the certainty of this finding. Importantly, most studies compared strengthening programs with conventional treatment or added modalities rather than directly comparing standardized hip/core and knee strengthening protocols.

The Pakistani evidence remains limited. Hussain et al. [3] reported a 71% prevalence of PFPS among sanitary workers in Lahore, highlighting its local clinical and occupational relevance; however, their cross-sectional design did not assess treatment effectiveness. Since most intervention studies have been conducted outside Pakistan [12, 14–21], their findings may not be directly generalizable to the local population. Therefore, the present study directly compares hip/core and knee strengthening exercises for pain, muscle strength, and functional disability in Pakistani patients with PFPS.

3. PROBLEM STATEMENT

Patellofemoral Pain Syndrome (PFPS) is a prevalent musculoskeletal disorder associated with anterior knee pain, muscle weakness, and functional limitations. Although conventional rehabilitation primarily focuses on knee and quadriceps strengthening, proximal deficits involving the hip and core may contribute to altered femoral control, dynamic knee valgus, and increased patellofemoral loading. Despite growing recognition of proximal strengthening in PFPS management, limited evidence from Pakistan directly compares hip/core strengthening with knee-focused strengthening. Therefore, this study aimed to compare their effects on pain, muscle strength, and functional disability among patients with PFPS in a Pakistani clinical setting.

4. OBJECTIVES AND HYPOTHESES

The present study aimed to compare the effects of hip and core strengthening exercises with knee strengthening exercises on pain intensity, muscle strength, functional disability, and functional performance in patients with Patellofemoral Pain Syndrome. The null hypothesis (H_0) stated that there would be no statistically significant difference between the two strengthening approaches in terms of pain intensity, muscle strength, functional disability, and functional performance. Conversely, the alternative hypothesis (H_1) proposed that a statistically significant difference would exist between hip and core strengthening exercises and knee strengthening exercises across these clinical outcomes.

5. MATERIAL AND METHODS**5.1 Study Design and Setting**

A randomized controlled trial was conducted to compare the effects of hip and core strengthening exercises with knee strengthening exercises on pain intensity, functional disability, and muscle strength in patients with Patellofemoral Pain Syndrome (PFPS). The study was conducted at Baba Bulley Shah Hospital, Kasur, Yaseen Medical Centre, and Orthopaedic Spine Care Clinic.

5.2 Sample Size and Participants

Sample size estimation was performed using G*Power with $\alpha = 0.05$ and 90% power for a two-tailed comparison between two independent groups. A previous study with 34 participants was used as a reference [17]. Accordingly, 30 eligible participants were recruited and equally allocated to the Hip/Core Strengthening Group ($n = 15$) and Knee Strengthening Group ($n = 15$).

Participants were male and female patients aged 20–40 years with PFPS who reported moderate anterior knee pain (VAS 3–7) aggravated by activities such as squatting, stair climbing, or prolonged sitting and were willing to undertake the prescribed exercise program. Patients with previous knee surgery or severe knee injury, ligamentous or meniscal pathology, osteoarthritis, neurological or other conditions affecting lower-limb function, concurrent treatment for knee pain, pregnancy, or contraindications to exercise were excluded.

5.3 Randomization and Blinding

Participants fulfilling the eligibility criteria and providing informed consent were randomly allocated to either intervention group using a computer-generated randomization sequence. Allocation assignments were placed in sequentially numbered, opaque, sealed envelopes and opened after completion of baseline assessment. The study employed a single-blinded design, whereby the outcome assessor remained unaware of group allocation. Blinding of participants and the treating physiotherapist was not feasible because of the distinct exercise protocols. Participants were instructed not to disclose their allocation to the assessor.

5.4 Sampling and Study Duration

Participants were recruited using purposive sampling from the selected clinical settings. The study was completed over six months, including recruitment, baseline assessment, intervention, post-intervention assessment, and data analysis. The intervention period lasted 12 weeks.

5.5 Study Variables and Outcome Measures

The independent variables were hip and core strengthening exercises and knee strengthening exercises. The primary outcome measures were pain intensity, functional disability, and muscle strength, assessed using the Visual Analogue Scale (VAS), Kujala Patellofemoral Questionnaire, and hand-held dynamometer (HHD), respectively.

5.6 Outcome Measurement Tools

Pain intensity, functional disability, and muscle strength were assessed using the Visual Analogue Scale (VAS), Kujala Patellofemoral Score, and Hand-held Dynamometer (HHD), respectively. These instruments were selected for their established clinical utility, validity, and reliability in assessing PFPS-related outcomes.

5.6.1 Visual Analogue Scale (VAS)

Pain intensity was assessed using a 10-cm horizontal VAS ranging from 0 (no pain) to 10 (worst possible pain). Participants marked their perceived pain intensity, and the distance from zero to the mark was recorded in centimeters. Scores were interpreted as 0–1 (no pain), 2–3 (mild), 4–6 (moderate), 7–8 (severe), and 9–10 (worst possible pain). The VAS has demonstrated excellent reliability, with an ICC of 0.97 (95% CI: 0.96–0.98) [22].

5.6.2 Kujala Patellofemoral Score

Functional disability was evaluated using the 13-item, self-administered Kujala Patellofemoral Score, with total scores ranging from 0 to 100. Higher scores indicate better knee function and lower disability. The questionnaire assesses symptoms and functional limitations associated with activities including walking, running, jumping, stair climbing, squatting, and prolonged sitting. Scores of 95–100 indicate normal function, 85–94 mild dysfunction, 70–84 moderate dysfunction, and 50–69 severe

dysfunction. The instrument has demonstrated high reliability and validity, with an ICC of 0.96 [23, 24].

5.6.3 Hand-held Dynamometer (HHD)

Maximum isometric strength of the selected lower-limb muscles, particularly the quadriceps and hip abductors, was assessed using an HHD. Strength was recorded quantitatively in kilograms or pounds and used to identify muscular deficits and monitor changes following rehabilitation. A bilateral strength difference exceeding 10–15% was considered indicative of weakness. Values below 80% of age-, sex-, and body-mass-adjusted normative values may be considered low, 80–100% normal, and >100% high. HHD provides an objective measure of muscle force and is useful for evaluating rehabilitation progress in patients with PFPS [25].

5.7 Intervention Protocols

All participants received the same conventional physiotherapy program before the assigned strengthening intervention. This comprised moist heat to the affected knee for 10–15 minutes, TENS as clinically indicated and tolerated, gentle patellar mobilization, and soft-tissue mobilization of the quadriceps and hamstrings. Following conventional treatment, participants completed the strengthening program corresponding to their allocated group. Both programs were performed under physiotherapist supervision three times weekly for 12 weeks, with progression based on exercise tolerance and maintenance of correct technique.

Group I: Hip and Core Muscle Strengthening

The hip and core strengthening program was adapted from previously published protocols [12, 14, and 15]. The exercises, dosage, targeted musculature, and progression criteria are presented in Table 1.

Table 1. Hip and Core Muscle Strengthening Protocol

Exercise	Dosage	Primary Muscles	Target	Progression
Resistance-band hip abduction	3 × 10–15 repetitions, 3 sessions/week	Gluteus medius, gluteus minimus		Increase band resistance after 15 repetitions are completed with correct technique
Side-lying hip lift	3 × 12 repetitions, 3 sessions/week	Gluteus medius, core stabilisers		Add ankle weight when 12 repetitions are performed comfortably
Plank	3 × 20–40 seconds, 3 sessions/week	Rectus abdominis, transversus abdominis, obliques		Increase hold duration by 10–15 seconds as tolerated
Bird-dog	3 × 10 repetitions/side, 3 sessions/week	Erector spinae, multifidus, gluteus maximus		Increase hold duration or add light ankle/wrist resistance
Side plank	3 × 15–30 seconds/side, 3 sessions/week	Obliques, gluteus medius, core stabilisers		Increase hold duration or incorporate hip abduction when stable

Group II: Knee Muscle Strengthening

The knee strengthening program was similarly adapted from previously published protocols [12,

14, and 15]. The exercise prescription and progression criteria are presented in Table 2.

Table 2. Knee Muscle Strengthening Protocol

Exercise	Dosage	Primary Muscles	Target	Progression
Quadriceps setting	3 × 15 repetitions, 3 sessions/week	Quadriceps		Add ankle weight or resistance band when 15 repetitions are completed comfortably
Straight-leg raise	3 × 12–15 repetitions, 3 sessions/week	Quadriceps, hip flexors		Increase repetitions or add ankle weight after 15 repetitions become manageable
Short-arc quadriceps	3 × 10–15 repetitions, 3 sessions/week	Quadriceps		Increase resistance or use a foam roller to increase difficulty
Resistance-band terminal knee extension	3 × 12 repetitions, 3 sessions/week	Quadriceps		Increase band resistance after 12 repetitions are completed with correct technique
Step-ups	3 × 10 repetitions, 3 sessions/week	Quadriceps, gluteus maximus		Increase step height or add external resistance when repetitions are completed without excessive fatigue

5.8 Ethical Considerations

Ethical approval and institutional permissions were obtained before data collection. All participants provided written informed consent

after being informed about the study procedures, benefits, risks, confidentiality, and their right to withdraw without consequence.

5.9 Data Collection Procedure

The six-month randomized controlled trial included 30 male and female participants aged 20–40 years with PFPS, allocated equally to two groups ($n = 15$) through computer-generated randomization with concealed allocation. The outcome assessor was blinded to group assignment. Both groups received identical conventional physiotherapy, followed by either hip/core or knee strengthening exercises, three times weekly for 12 weeks under supervision. VAS, Kujala Patellofemoral Score, and HHD were recorded at baseline and after 12 weeks.

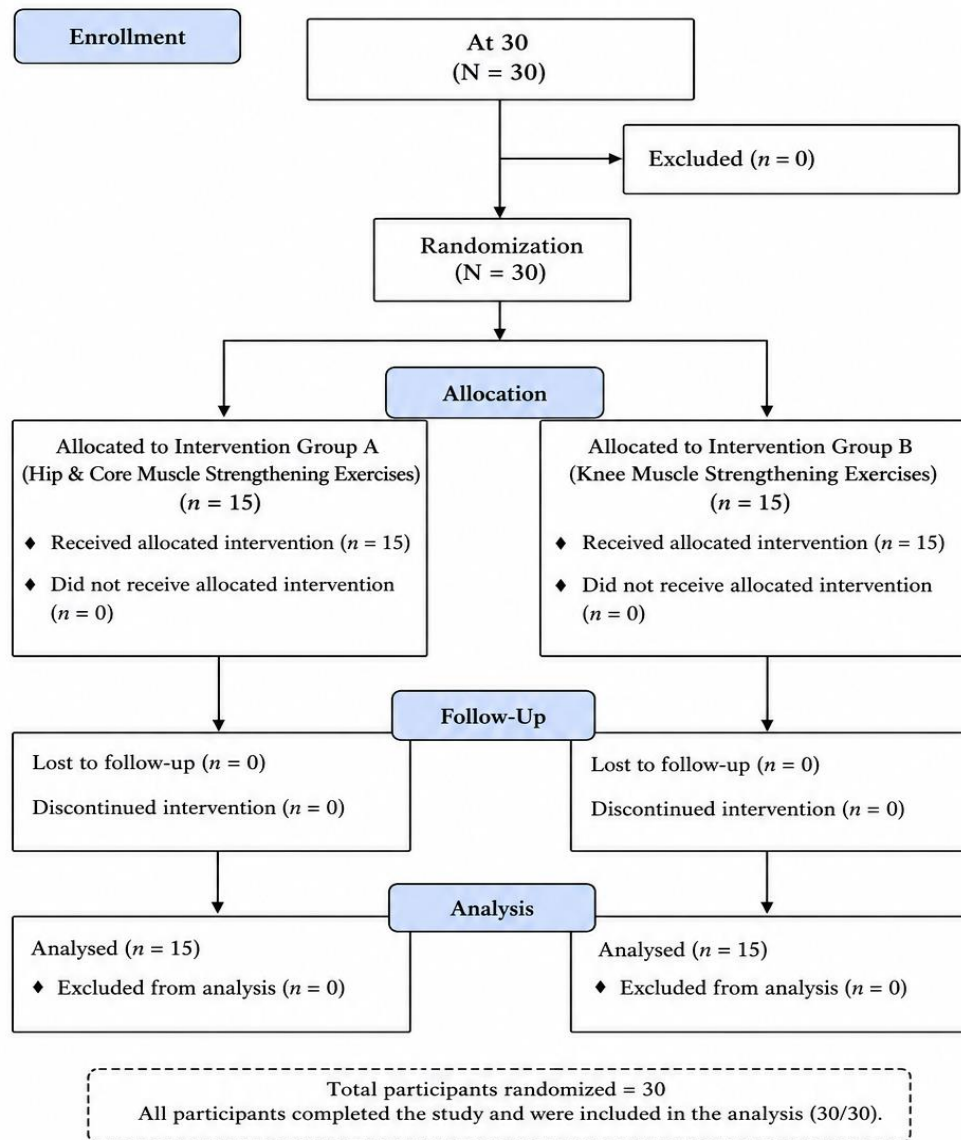
5.10 Data Analysis

Data were analyzed using IBM SPSS Statistics version 26.0. Descriptive statistics were reported as mean $\pm$ SD, frequencies, and percentages. Normality was assessed using the Shapiro-Wilk test. Paired-samples and independent-samples t -tests were used for normally distributed within- and between-group data, respectively, while appropriate non-parametric tests were applied otherwise. Statistical significance was set at $p \leq 0.05$.



CONSORT FLOW DIAGRAM

Comparing the Effects of Hip and Core Muscle Strengthening Exercises
and Knee Muscle Strengthening Exercises on Pain Intensity,
Functional Disability and Muscle Strength in Patients with
Patellofemoral Pain Syndrome



6. RESULTS

6.1 Baseline Demographic and Clinical Characteristics of Participants

The Hip/Core group was older on average and had a slightly higher mean BMI, whereas the Knee

group had a longer mean symptom duration. The Hip/Core group had more male participants, while females were slightly more represented in the Knee group. High-income participants were the largest category in both groups (Table 3).

Table 3 Baseline Demographic and Clinical Characteristics of Participants

Variable	Hip/Core Group (n = 15)	Knee Group (n = 15)
Age (years), mean $\pm$ SD	31.73 $\pm$ 6.87	26.20 $\pm$ 6.70
BMI (kg/m ²), mean $\pm$ SD	25.93 $\pm$ 3.29	25.53 $\pm$ 3.07
Duration of symptoms (months), mean $\pm$ SD	9.20 $\pm$ 4.25	11.07 $\pm$ 5.44
Gender, n (%)		
Male	9 (60.0)	7 (46.7)
Female	6 (40.0)	8 (53.3)
Income, n (%)		
Low	5 (33.3)	5 (33.3)
Middle	3 (20.0)	4 (26.7)
High	7 (46.7)	6 (40.0)

Note. BMI = body mass index; SD = standard deviation.

6.2 Clinical Outcome Measures

The comparison of pre- and post-intervention outcomes for pain intensity, functional status, and muscle strength is presented in Table 4. Both the Hip/Core and Knee strengthening group's demonstrated improvement following the intervention, reflected by reductions in VAS scores and increases in Kujala and HHD scores. The overall comparison of clinical outcomes is presented in Table 4. Both groups demonstrated favorable changes after the intervention: VAS scores decreased from 6.18 $\pm$ 1.16 to 4.13 $\pm$ 1.25

in the Hip/Core group and from 5.85 $\pm$ 1.00 to 4.41 $\pm$ 1.10 in the Knee group. Conversely, Kujala scores increased from 55.20 $\pm$ 4.43 to 67.87 $\pm$ 6.42 and from 55.67 $\pm$ 6.06 to 66.60 $\pm$ 6.05, respectively, while HHD scores increased from 21.55 $\pm$ 3.01 to 26.50 $\pm$ 3.20 in the Hip/Core group and from 22.43 $\pm$ 4.10 to 26.51 $\pm$ 4.61 in the Knee group. Overall, both interventions improved pain, functional status, and muscle strength, with slightly greater improvements in VAS and Kujala scores observed in the Hip/Core group.

Table 4. Pre- and Post-Intervention Clinical Outcome Measures

Outcome measure	Group	Pre-intervention, Mean $\pm$ SD	Post-intervention, Mean $\pm$ SD
VAS score	Hip/Core	6.18 $\pm$ 1.16	4.13 $\pm$ 1.25
	Knee	5.85 $\pm$ 1.00	4.41 $\pm$ 1.10
Kujala score	Hip/Core	55.20 $\pm$ 4.43	67.87 $\pm$ 6.42
	Knee	55.67 $\pm$ 6.06	66.60 $\pm$ 6.05
HHD score	Hip/Core	21.55 $\pm$ 3.01	26.50 $\pm$ 3.20
	Knee	22.43 $\pm$ 4.10	26.51 $\pm$ 4.61

Note. M = mean; SD = standard deviation; VAS = Visual Analogue Scale; HHD = Hand-held Dynamometer. Higher Kujala and HHD scores indicate better functional status and greater muscle strength, whereas lower VAS scores indicate reduced pain.

6.3 Assessment of Data Distribution and Normality

This section presents the Shapiro-Wilk normality assessment conducted to determine the appropriate statistical tests for the clinical outcome variables. As shown in Table 5, most outcome variables demonstrated normal

distributions ($p > .05$). However, change scores for VAS and Kujala in the Hip/Core group were non-normally distributed ($p = .032$ and $.042$, respectively). Therefore, subsequent inferential analyses should account for these distributional differences when selecting parametric or non-parametric tests.

Table 5. Test of Normality Using the Shapiro–Wilk Test

Variable	Group	<i>n</i>	Shapiro–Wilk <i>W</i>	<i>p</i>	Normality
VAS Before	Hip/Core	15	0.889	0.064	Normal
VAS Before	Knee	15	0.910	0.134	Normal
VAS After	Hip/Core	15	0.900	0.095	Normal
VAS After	Knee	15	0.979	0.963	Normal
Kujala Before	Hip/Core	15	0.973	0.904	Normal
Kujala Before	Knee	15	0.972	0.890	Normal
Kujala After	Hip/Core	15	0.940	0.389	Normal
Kujala After	Knee	15	0.978	0.953	Normal
HHD Before	Hip/Core	15	0.930	0.276	Normal
HHD Before	Knee	15	0.916	0.169	Normal
HHD After	Hip/Core	15	0.884	0.055	Normal
HHD After	Knee	15	0.960	0.700	Normal
Change VAS	Hip/Core	15	0.868	0.032	Not normal
Change VAS	Knee	15	0.918	0.179	Normal
Change Kujala	Hip/Core	15	0.876	0.042	Not normal
Change Kujala	Knee	15	0.907	0.121	Normal
Change HHD	Hip/Core	15	0.926	0.235	Normal
Change HHD	Knee	15	0.884	0.054	Normal

Note. *W* = Shapiro–Wilk statistic; *p* < .05 indicates a statistically significant departure from normality.

6.4 Within-Group Comparison of Clinical Outcomes

Within-group changes from pre- to post-intervention were analyzed using the paired-samples *t*-test. As shown in Table 6, both the Hip/Core and Knee strengthening groups demonstrated statistically significant improvements in all clinical outcomes. VAS scores decreased significantly in the Hip/Core group from 6.18 ± 1.16 to 4.13 ± 1.25 ($t = 12.44$, $p < .001$) and in the Knee group from 5.85 ± 1.00 to

4.41 ± 1.10 ($t = 11.99$, $p < .001$). Kujala scores increased significantly in the Hip/Core group from 55.20 ± 4.43 to 67.87 ± 6.42 ($t = -13.13$, $p < .001$) and in the Knee group from 55.67 ± 6.06 to 66.60 ± 6.05 ($t = -13.25$, $p < .001$). Similarly, HHD scores increased from 21.55 ± 3.01 to 26.50 ± 3.20 in the Hip/Core group ($t = -17.64$, $p < .001$) and from 22.43 ± 4.10 to 26.51 ± 4.61 in the Knee group ($t = -11.88$, $p < .001$), indicating significant improvements in muscle strength following intervention.

Table 6 Within-Group Comparison of Clinical Outcomes before and After Intervention

Outcome	Group	Pre-intervention, <i>M</i> ± <i>SD</i>	Post-intervention, <i>M</i> ± <i>SD</i>	<i>t</i>	<i>df</i>	<i>p</i>
VAS	Hip/Core	6.18 ± 1.16	4.13 ± 1.25	12.44	14	< .001
	Knee	5.85 ± 1.00	4.41 ± 1.10	11.99	14	< .001
Kujala	Hip/Core	55.20 ± 4.43	67.87 ± 6.42	-13.13	14	< .001
	Knee	55.67 ± 6.06	66.60 ± 6.05	-13.25	14	< .001
HHD	Hip/Core	21.55 ± 3.01	26.50 ± 3.20	-17.64	14	< .001
	Knee	22.43 ± 4.10	26.51 ± 4.61	-11.88	14	< .001

Note. *M* = mean; *SD* = standard deviation; VAS = Visual Analogue Scale; HHD = Hand-held Dynamometer.

6.5 Between-Group Comparisons of Changes in Clinical Outcomes

Between-group differences in change scores were assessed using the Mann-Whitney U test for VAS and Kujala scores and the independent-samples t-test for HHD scores. As presented in Table 7, the Hip/Core group demonstrated a significantly greater improvement in VAS scores than the Knee group ($U = 50.50$, $Z = -2.58$, $p = .010$). In

contrast, the difference in Kujala score changes was not statistically significant ($U = 86.00$, $Z = -1.11$, $p = .268$). Similarly, HHD scores increased by 4.95 ± 1.09 in the Hip/Core group compared with 4.09 ± 1.33 in the Knee group; however, the between-group difference was not statistically significant ($t = 1.95$, $p = .061$). Overall, the Hip/Core intervention showed a significant advantage only for pain reduction.

Table 7 Between-Group Comparison of Changes in Clinical Outcomes

Outcome	Group	<i>n</i>	Mean Rank / $M \pm SD$	Test statistic	<i>p</i>
Change in VAS	Hip/Core	15	19.63	$U = 50.50$, $Z = -2.58$	.010
	Knee	15	11.37		
Change in Kujala	Hip/Core	15	17.27	$U = 86.00$, $Z = -1.11$	.268
	Knee	15	13.73		
Change in HHD	Hip/Core	15	4.95 ± 1.09	$t = 1.95$	.061
	Knee	15	4.09 ± 1.33		

Note. VAS = Visual Analogue Scale; HHD = Hand-held Dynamometer; U = Mann-Whitney U statistic; Z = standardized test statistic; t = independent-samples t -test.

7. Discussion

The present randomized clinical trial demonstrated that both hip/core and knee strengthening programs significantly improved pain, functional status, and muscle strength in patients with PFPS. However, the Hip/Core group produced a significantly greater reduction in pain than the Knee group, whereas no significant between-group differences were observed in functional status or muscle strength. The improvement in VAS scores in the Hip/Core group from 6.18 ± 1.16 to 4.13 ± 1.25 was greater than that observed in the Knee group, which decreased from 5.85 ± 1.00 to 4.41 ± 1.10 , with a significant between-group difference in change ($p = .010$). This finding is consistent with Tazesh et al. [27], who reported significant pain reduction following both routine and core-stability exercise, with greater improvements favoring the core-stability approach. Similarly, Manojlovic et al. [28] reported greater pain reduction with hip-and-knee strengthening than knee-focused exercise ($MD = -1.71$, 95% CI -3.11 to -0.30 ; $p = .02$). The greater pain reduction observed with hip/core strengthening in the present study may be

attributed to improved proximal neuromuscular control, particularly of the hip abductors and external rotators, which may reduce excessive femoral internal rotation and dynamic knee valgus and consequently decrease patellofemoral loading. Differences in exercise selection, training intensity, duration, and participant characteristics may also explain variations between studies.

Both groups also showed significant improvements in Kujala scores, increasing from 55.20 ± 4.43 to 67.87 ± 6.42 in the Hip/Core group and from 55.67 ± 6.06 to 66.60 ± 6.05 in the Knee group ($p < .001$); however, the between-group difference was not significant ($p = .268$). These findings are comparable with Almeida et al. [34], who found significant improvements in functional outcomes following hip-strengthening interventions combined with knee strengthening but no significant difference between intervention groups. Manojlovic et al. [28] likewise reported significant functional benefits from hip and combined strengthening, although substantial heterogeneity was present among the included studies. The absence of a significant difference in the present study may be explained by the

relatively small sample size ($n = 15$ per group), the similar overall exercise dosage, and the fact that both groups received conventional physiotherapy in addition to strengthening. Furthermore, functional recovery in PFPS may depend on multiple factors, including pain reduction, muscle capacity, movement control, and daily activity, rather than proximal or knee strengthening alone. Muscle strength measured using HHD increased significantly in both groups, from 21.55 ± 3.01 to 26.50 ± 3.20 in the Hip/Core group and from 22.43 ± 4.10 to 26.51 ± 4.61 in the Knee group ($p < .001$). Nevertheless, the between-group difference was not statistically significant ($p = .061$). This finding agrees with Alqarni et al. [35], who reported that combined hip-and-knee strengthening improved pain and functional activity but did not produce a significant advantage in muscle strength compared with knee strengthening alone (SMD = 0.20, 95% CI -0.31 to 0.71; $p = .44$). Kamel et al. [29] also reported improvements in muscle strength and functional status following hip and knee strengthening, while Basbug et al. [32] demonstrated significant strength improvements following a 12-week neuromuscular exercise program. The similar strength gains between groups in the present study may be because both programs provided progressive resistance training and both groups received the same conventional physiotherapy, resulting in comparable exposure to therapeutic exercise. The slightly greater numerical improvement in the Hip/Core group did not reach statistical significance, possibly because of the limited sample size and variability in individual strength responses [34].

The present findings also differ from Pompeo et al. [33], who reported comparable pain reduction between hip/core-focused and leg/foot-focused exercise programs, whereas the current study demonstrated a significant between-group advantage for Hip/Core strengthening ($p = .010$). This discrepancy may be related to differences in exercise composition, intervention dosage, participant characteristics, and the inclusion of core exercises alongside hip strengthening in the present protocol. Boitrage et al. [30] similarly

demonstrated significant improvements in pain and functional outcomes following strengthening and proprioceptive exercises, supporting the overall effectiveness of exercise-based rehabilitation for PFPS. Collectively, the current findings indicate that both hip/core and knee strengthening are effective approaches for improving clinical outcomes in PFPS, while hip/core strengthening may offer an additional benefit for pain reduction. The lack of significant between-group differences in Kujala and HHD outcomes suggests that neither approach can be considered universally superior for functional recovery or muscle-strength gains [35].

8 Conclusion

Both hip/core and knee muscle strengthening programs significantly improved pain, functional status, and muscle strength in patients with PFPS. However, the Hip/Core group demonstrated a significantly greater reduction in pain than the Knee group, while improvements in functional status and muscle strength were comparable between groups. Therefore, hip/core strengthening may provide an additional benefit for pain management in PFPS.

9 Limitations

The study had a small sample size of 30 participants, which may limit the generalizability of the findings. The participants were restricted to 20–40 years, and purposive sampling may have introduced selection bias. In addition, only selected clinical outcomes were assessed, without evaluating other biomechanical or psychosocial factors associated with PFPS.

10 Recommendations

Future studies should include larger and more diverse populations and compare different combinations and intensities of hip, core, and knee strengthening exercises. Long-term follow-up studies are also recommended to determine whether improvements in pain, function, and muscle strength are maintained after completion of the intervention.

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