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EVIDENCE-BASED REHABILITATION APPROACHES FOR PATELLOFEMORAL PAIN SYNDROME: A SYSTEMATIC REVIEW

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Abstract

Background

Patellofemoral Pain Syndrome (PFPS) is one of the most common musculoskeletal disorders affecting adolescents, physically active individuals, and athletes. It is characterized by anterior knee pain aggravated by activities such as running, stair climbing, squatting, and prolonged sitting. Despite the widespread use of rehabilitation interventions, uncertainty remains regarding the most effective evidence-based rehabilitation strategies for managing PFPS.

Objective

To systematically evaluate and synthesize evidence published between April, 2015 and April, 2025 regarding the effectiveness of rehabilitation interventions for Patellofemoral Pain Syndrome.

Methods

A systematic review was conducted according to PRISMA guidelines. Electronic databases including PubMed, Scopus, PEDro, Web of Science, and Google Scholar were searched for studies published between 2015 and 2025. Randomized controlled trials, clinical trials, cohort studies, and systematic reviews investigating rehabilitation interventions for PFPS were included. Methodological quality was assessed using the PEDro scale. Data were synthesized narratively due to heterogeneity in intervention protocols and outcome measures.

Results

A total of 34 studies involving more than 2,000 participants met the inclusion criteria. Combined hip and knee strengthening interventions demonstrated the most consistent evidence for reducing pain and improving functional performance. Neuromuscular training and gait retraining also showed favorable effects on movement quality, lower limb biomechanics, and functional outcomes. Patellar taping and foot orthoses provided moderate short-term symptomatic benefits when combined with exercise therapy. Passive modalities, including ultrasound and electrical stimulation, demonstrated limited evidence for sustained long-term effectiveness when used independently.

Conclusion

Exercise-based rehabilitation remains the most effective conservative management approach for PFPS. Multimodal rehabilitation programs integrating hip and knee strengthening, neuromuscular training, and movement retraining produce superior clinical outcomes compared to isolated interventions. Individualized rehabilitation strategies targeting biomechanical and functional impairments are recommended for optimal management of PFPS.

INTRODUCTION

Patellofemoral Pain Syndrome (PFPS), commonly referred to as anterior knee pain, is a prevalent musculoskeletal disorder characterized by diffuse retro-patellar or peripatellar pain during functional activities involving knee flexion under load. The condition accounts for approximately 22–35% of knee-related complaints in sports medicine and physiotherapy clinics, particularly among adolescents, runners, and physically active populations (1). PFPS is considered multifactorial in origin, involving biomechanical, muscular, neuromuscular, and psychological contributors. Altered lower limb kinematics, quadriceps weakness, hip abductor dysfunction, excessive foot pronation, and abnormal patellar tracking are frequently associated with symptom development (2). Pain is commonly aggravated by activities such as stair climbing, squatting, running, jumping, and prolonged sitting (3).

Over the last decade, rehabilitation strategies for PFPS have evolved considerably. Earlier management approaches emphasized isolated quadriceps strengthening, particularly targeting the vastus medialis oblique (VMO). Contemporary evidence increasingly supports a broader kinetic chain approach incorporating hip strengthening, neuromuscular control, movement retraining, and biomechanical correction (4). Several studies published after 2015 demonstrated the importance of proximal muscle function in PFPS management. Weakness of the hip abductors and external rotators has been associated with increased femoral internal rotation and dynamic knee valgus, contributing to abnormal patellofemoral joint loading (5). Consequently, rehabilitation protocols incorporating hip-focused strengthening exercises have gained prominence in clinical practice.

Exercise therapy remains the primary conservative intervention for PFPS. Systematic reviews have consistently reported clinically meaningful improvement in pain and function following structured strengthening programs (6). Combined hip and knee strengthening appears more effective than isolated quadriceps exercises, especially in female athletes and physically active individuals (7). Neuromuscular training and movement retraining have also gained attention in recent years. Abnormal movement patterns during running, landing, and squatting contribute to increased patellofemoral joint stress. Interventions targeting gait mechanics, landing control, and dynamic alignment have demonstrated promising outcomes (8).

Adjunctive interventions including patellar taping, foot orthoses, manual therapy, dry needling, and electrotherapy have been

investigated with variable findings. Patellar taping may provide short-term pain relief by improving patellar alignment and reducing joint stress (9). Similarly, foot orthoses may benefit patients with excessive pronation and altered lower extremity biomechanics (10). Despite the growing body of literature, inconsistencies remain regarding optimal rehabilitation protocols, intervention duration, exercise dosage, and long-term outcomes. Many previous reviews included heterogeneous populations and mixed intervention approaches, limiting clinical applicability (11).

Although previous systematic reviews have evaluated exercise therapy and isolated strengthening interventions for PFPS, limited evidence syntheses have comprehensively examined multimodal rehabilitation strategies published during the last decade. Furthermore, recent rehabilitation approaches including neuromuscular training, gait retraining, and movement-based interventions have not been consistently integrated within earlier reviews. Variability in rehabilitation protocols, intervention duration, outcome measures, and patient characteristics also limits the clinical applicability of existing evidence. Therefore, an updated systematic review is necessary to evaluate contemporary evidence regarding rehabilitation interventions for PFPS and provide clinically relevant recommendations for physiotherapy practice.

Objective

The objective of this systematic review was to evaluate and synthesize evidence published between 2015 and 2025 regarding rehabilitation approaches for Patellofemoral Pain Syndrome (PFPS). The review specifically aimed to:

1. Identify the most effective physiotherapy and rehabilitation interventions for reducing pain and improving functional outcomes in individuals with PFPS.
2. Compare the effectiveness of hip strengthening, quadriceps strengthening, neuromuscular training, gait retraining, taping, foot orthoses, and other conservative rehabilitation strategies.
3. Examine current evidence regarding multimodal rehabilitation programs and their clinical effectiveness.
4. Provide evidence-based recommendations for physiotherapists and rehabilitation professionals involved in PFPS management.
5. Identify gaps in current literature and suggest directions for future research in PFPS rehabilitation.

MATERIAL AND METHODS

Study Design

This was a systematic review to evaluate evidence-based rehabilitation interventions for Patellofemoral Pain Syndrome (PFPS). The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure methodological transparency and reporting quality.

Data Sources and Search Strategy

A comprehensive electronic literature search was performed using the databases including PubMed/MEDLINE, Scopus, PEDro (Physiotherapy Evidence Database), Web of Science and Google Scholar. The electronic database search was conducted between April, 2025, and April, 2025. The selected timeframe was chosen to capture contemporary rehabilitation approaches and recent advances in conservative management of PFPS. A combination of Medical Subject Headings (MeSH) terms and free-text keywords was used. Boolean operators ("AND" and "OR") were applied to optimize the search strategy.

The primary search terms included**:**

"Patellofemoral Pain Syndrome", "Patellofemoral Pain", "Anterior Knee Pain", "Rehabilitation", "Physiotherapy", "Exercise Therapy", "Hip Strengthening", "Quadriceps Strengthening", "Neuromuscular Training", "Gait Retraining" "Conservative Management"

Example Search Syntax (PubMed)
("Patellofemoral Pain Syndrome"[Mesh] OR "Patellofemoral Pain" OR "Anterior Knee Pain")AND ("Rehabilitation" OR "Physiotherapy" OR "Exercise Therapy" OR "Hip Strengthening" OR "Neuromuscular Training")
Additionally, reference lists of included studies and relevant systematic reviews were manually screened to identify potentially eligible articles not captured during the electronic search.

Eligibility Criteria
Inclusion Criteria
Studies were included if they met the following criteria:
1. Published between 2015 and 2025.
2. Included participants clinically diagnosed with PFPS or anterior knee pain.
3. Investigated rehabilitation or conservative physiotherapy interventions.
4. Examined outcomes related to pain, function, muscle strength, biomechanics, or physical performance.
5. Randomized controlled trials (RCTs), quasi-experimental studies, clinical trials, cohort studies, or systematic reviews.
6. Published in peer-reviewed journals.
7. Published in the English language.

Exclusion Criteria
Studies were excluded if they:
1. Included postoperative or surgical patients.
2. Investigated patellar instability, ligament injuries, fractures, osteoarthritis, or other non-PFPS knee disorders.
3. Were case reports, conference abstracts, editorials, letters, or dissertations.
4. Included pediatric populations with non-specific knee pathology.
5. Lacked full-text availability.
6. Used pharmacological or invasive interventions without rehabilitation components.

Screening and Selection Process
Two independent reviewers screened titles, abstracts, and full-text articles according to the predefined eligibility criteria. In cases of uncertainty, a third reviewer was consulted to ensure consistency in study selection. The study selection process was completed in three stages: Firstly, Titles were screened based on relevance to PFPS rehabilitation. Abstracts of potentially relevant studies were independently reviewed according to the eligibility criteria. Afterwards, Full-text articles were assessed for final inclusion. Disagreements during the screening process were resolved through discussion and consensus based on study eligibility criteria.

Data Extraction
A standardized data extraction form was developed to ensure consistency across included studies. The data regarding Author(s) and publication year, Country of study, Study design, Sample size, Participant characteristics (age, gender, activity level), Type of rehabilitation intervention, duration and frequency of the intervention, Outcome measures used, Follow-up duration and their Main findings and clinical outcomes were extracted for the study.

Outcome Measures
The primary outcomes assessed in this review included Visual Analog Scale (VAS) and Numeric Pain Rating Scale (NPRS) to assess pain. Kujala Anterior Knee Pain Scale, Lower Extremity Functional Scale (LEFS) and Functional Index Questionnaire (FIQ) were used for Functional Assessment. Hip abductor strength, Quadriceps strength, Dynamic knee valgus, Gait mechanics, and Movement quality were used to assess Biomechanical and Strength Outcomes. Secondary outcomes included quality of life, return to activity, and patient satisfaction.

Quality Assessment Revision
Methodological quality appraisal of randomized controlled trials was conducted using the PEDro scale. Studies were categorized as excellent, good, fair, or poor quality according to PEDro scoring criteria. PEDro scores were interpreted as follows:
- 9–10 = excellent quality
- 6–8 = good quality

- 4–5 = fair quality
- below 4 = poor quality

Risk of bias was evaluated based on randomization, allocation concealment, blinding, attrition reporting, selective outcome reporting and intention-to-treat analysis. Systematic reviews included in this study were critically appraised using the AMSTAR-2 criteria.

Data Synthesis

Due to heterogeneity in intervention protocols, treatment duration, and outcome measures, a narrative synthesis approach was adopted instead of meta-analysis. Studies were categorized according to intervention type including Hip strengthening exercises, Quadriceps strengthening, Combined kinetic chain rehabilitation, Neuromuscular training, Gait retraining, Patellar taping, Foot orthoses and Electrotherapy modalities. Findings were synthesized based on intervention effectiveness, consistency of outcomes, and methodological quality.

Ethical Considerations

Ethical approval was not required because this study involved analysis of previously published data and did not include human participant recruitment or direct patient involvement.

RESULTS

Study Selection

Figure 1 illustrates the detailed flow chart of the included study. The database search identified a total of 1,284 records from PubMed, Scopus, PEDro, Web of Science, and Google Scholar. After removal of 272 duplicate articles, 1,012 studies remained for title and abstract screening. Following the screening process, 936 articles were excluded due to irrelevance, inappropriate study design, or failure to meet eligibility criteria. Seventy-six full-text articles were assessed for eligibility. Of these, 42 studies were excluded for reasons including non-rehabilitation interventions, insufficient outcome data, mixed knee pathologies, postoperative populations, or low methodological quality. Ultimately, 34 studies were included in the qualitative synthesis. The included studies consisted of 24 randomized controlled trials, 5 clinical trials, 3 cohort studies and 2 systematic reviews.

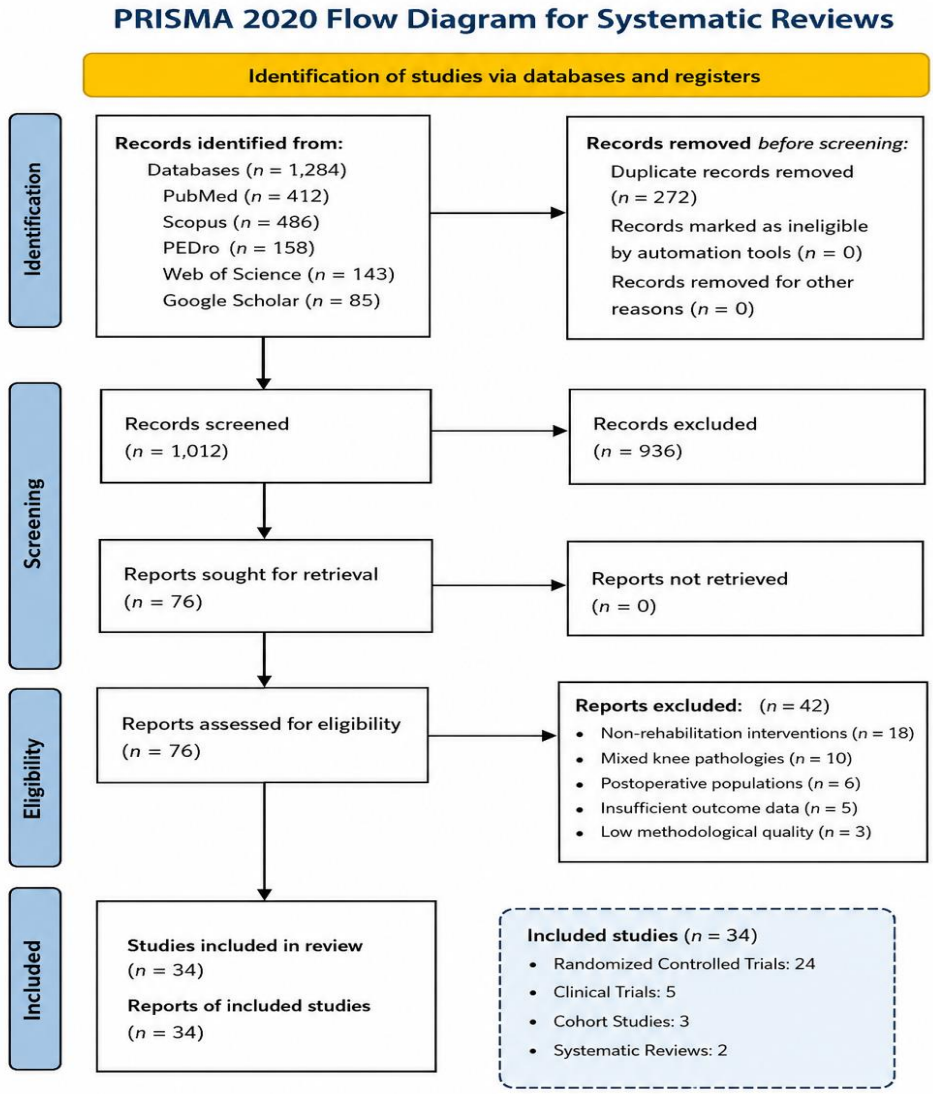

Figure 1. PRISMA 2020 flow diagram showing the selection process of studies included in the systematic review.

Characteristics of Included Studies

The included studies involved more than 2,000 participants diagnosed with PFPS. Sample sizes ranged from 20 to 240 participants. Most studies included physically active adults, runners, recreational athletes, and adolescents aged between 16 and 40 years. Female participants represented the majority population across most studies, reflecting the higher prevalence of PFPS among women. Intervention duration ranged from 4 to 24 weeks, with most rehabilitation programs lasting between 6 and 12 weeks. The primary interventions investigated included hip strengthening, quadriceps strengthening, combined kinetic chain rehabilitation, neuromuscular training, gait retraining, patellar taping, foot orthoses, manual therapy, and electrotherapy modalities. The primary rehabilitation interventions identified included Hip strengthening exercises, Quadriceps strengthening exercises, Combined hip and knee rehabilitation, Neuromuscular training, Gait retraining, Patellar taping, Foot orthoses, Manual therapy and Electrotherapy modalities.

Table 1. Characteristics of Included Studies

Author	Year	Study Design	Sample Size	Intervention	Duration	Outcome Measures	Main Findings
Ferber et al. (7)	2015	RCT	199	Hip and knee strengthening	6 weeks	VAS, LEFS	Significant pain reduction and improved function
Khayambashi et al. (12)	2012	RCT	28	Hip strengthening	8 weeks	VAS, Kujala Score	Improved pain and functional performance
Collins et al. (4)	2018	Clinical Trial	179	Foot orthoses	6 weeks	NPRS, FIQ	Moderate improvement in pain
Baldon et al. (11)	2015	RCT	40	Functional stabilization training	8 weeks	VAS, LEFS	Improved dynamic knee control
Willy and Davis (2)	2019	Clinical Trial	68	Gait retraining	6 weeks	VAS, Running Mechanics	Reduced patellofemoral joint stress
Esculier et al. (8)	2018	RCT	69	Neuromuscular retraining	8 weeks	Kujala Score, LEFS	Improved biomechanics and pain
Barton et al. (9)	2015	Systematic Review	14 studies	Patellar taping	Variable	Pain scales	Short-term pain relief observed
K. Kadłubowska et al. (13)	2015	Literature Review	54	Electrotherapy and exercise	6 weeks	NPRS, Kujala Score	Exercise superior to electrotherapy alone
Prins and van der Wurff (14)	2017	Cohort Study	36	Hip abductor strengthening	8 weeks	LEFS, Strength testing	Improved lower limb alignment
Neal et al. (5)	2019	Systematic Review	21 studies	Multimodal rehabilitation	Variable	Functional outcomes	Strong evidence for combined rehabilitation

Quality Assessment

Methodological quality assessment using the PEDro scale demonstrated that the majority of randomized controlled trials were of moderate to high quality. 11 studies were rated as excellent quality (PEDro score 9–10), 16 studies were of good quality (PEDro score 6–8), 5 studies were rated as fair quality (PEDro score 4–5), while only 2 studies demonstrated low methodological quality. The most common methodological limitations included lack of therapist blinding, limited long-term follow-up, and inconsistent allocation concealment.

Risk of Bias Assessment

The overall methodological quality of included studies was moderate to high. Common sources of bias included lack of therapist blinding, inadequate allocation concealment, and limited long-term follow-up assessment. Several studies also demonstrated heterogeneity in exercise dosage, intervention progression, and outcome reporting methods. Despite these limitations, most randomized controlled trials demonstrated acceptable methodological rigor and low risk of major selection bias.

Table 2. Methodological Quality Assessment Using PEDro Scale

Study	PEDro Score	Quality Rating
Ferber et al. (7)	9/10	Excellent
Khayambashi et al. (12)	8/10	Good
Baldon et al. (11)	8/10	Good
Esculier et al. (8)	9/10	Excellent
Willy and Huglund et al. (2)	7/10	Good
Kadłubowska et al. (13)	6/10	Good
Collins et al. (6)	8/10	Good
Prins et al. (14)	6/10	Good
Neal et al. (5)	9/10	Excellent
Barton et al. (9)	8/10	Good

Effects of Hip and Knee Strengthening Programs

Combined hip and knee strengthening demonstrated the strongest and most consistent evidence for reducing pain and improving functional outcomes in individuals with PFPS. Across multiple randomized controlled trials, participants receiving combined strengthening interventions showed significantly greater improvements in pain scores and functional performance compared to isolated quadriceps strengthening programs. Hip-focused rehabilitation commonly targeted Gluteus medius, Gluteus maximus and Hip external rotators. These interventions improved lower limb biomechanics by reducing dynamic knee valgus and excessive femoral internal rotation during functional tasks. Several studies reported clinically meaningful reductions in pain within 6–8 weeks of intervention. Improvements were also observed in stair climbing, squatting, running tolerance, and daily functional activities. Isolated quadriceps strengthening produced moderate improvements in pain and function but demonstrated inferior outcomes compared to combined kinetic chain approaches.

Neuromuscular Training and Movement Retraining

Neuromuscular rehabilitation interventions demonstrated moderate-to-strong evidence for improving movement quality and reducing patellofemoral joint stress. Programs focusing on movement control, balance training, functional alignment and dynamic stabilization showed positive effects on lower extremity mechanics during squatting, landing, and running activities. Gait retraining interventions were particularly effective in runners with PFPS. Studies reported reductions in pain intensity and improved running mechanics following cadence modification and correction of excessive hip adduction. Several trials demonstrated that movement retraining combined with strengthening exercises produced more consistent outcomes compared to strengthening alone.

Patellar Taping

Patellar taping demonstrated short-term effectiveness in reducing pain during functional activities. Most studies reported immediate symptom relief during stair climbing, squatting, and walking tasks. However, the long-term benefits of taping alone were limited. Better outcomes were observed when taping was

combined with structured exercise therapy. The effectiveness of taping appeared to vary depending on individual biomechanical characteristics and patellar alignment patterns.

Foot Orthoses

Foot orthoses demonstrated moderate evidence for pain reduction in patients with excessive foot pronation and altered lower limb biomechanics. Studies reported improved comfort and functional performance when orthoses were used as adjuncts to exercise therapy. Patients with greater pronation-related biomechanical deficits showed more favorable outcomes. Evidence suggested that prefabricated orthoses produced similar short-term outcomes compared to customized orthotic devices in many cases.

Manual Therapy

Manual therapy interventions including patellofemoral mobilization, soft tissue release, and joint mobilization demonstrated limited-to-moderate short-term effectiveness. Most studies indicated that manual therapy alone was insufficient for long-term symptom resolution. Improved outcomes were reported when manual therapy was integrated with active rehabilitation programs.

Electrotherapy Modalities

Electrotherapy modalities including ultrasound therapy, transcutaneous electrical nerve stimulation (TENS), and neuromuscular electrical stimulation demonstrated limited evidence for long-term clinical effectiveness. Some studies reported temporary pain reduction; however, exercise-based interventions consistently produced superior functional improvements and longer-lasting outcomes. Current evidence does not support electrotherapy as a primary standalone treatment for PFPS.

Table 3. Summary of Rehabilitation Interventions and Evidence

Intervention Type	No. of Studies	Main Outcomes	Level of Evidence
Combined hip and knee strengthening	12	Reduced pain, improved function, improved biomechanics	Strong
Hip strengthening alone	7	Improved hip stability and pain reduction	Moderate to Strong
Quadriceps strengthening	5	Moderate improvement in pain and function	Moderate
Neuromuscular training	6	Improved movement control and dynamic stability	Moderate to Strong
Gait retraining	4	Improved running mechanics and reduced joint stress	Moderate
Patellar taping	4	Short-term pain relief	Moderate
Foot orthoses	5	Improved biomechanics and symptom relief	Moderate
Manual therapy	3	Temporary symptom improvement	Limited to Moderate
Electrotherapy modalities	4	Short-term pain reduction only	Limited

Overall Synthesis of Findings

The overall findings of this systematic review indicate that multimodal rehabilitation programs provide the most effective conservative management for PFPS. The strongest evidence supports Combined hip and knee strengthening, Neuromuscular and movement retraining and Individualized exercise-based rehabilitation. Adjunctive interventions such as taping and foot orthoses may enhance short-term symptom

management when biomechanical impairments are present. Passive modalities alone demonstrated limited effectiveness compared to active rehabilitation strategies.

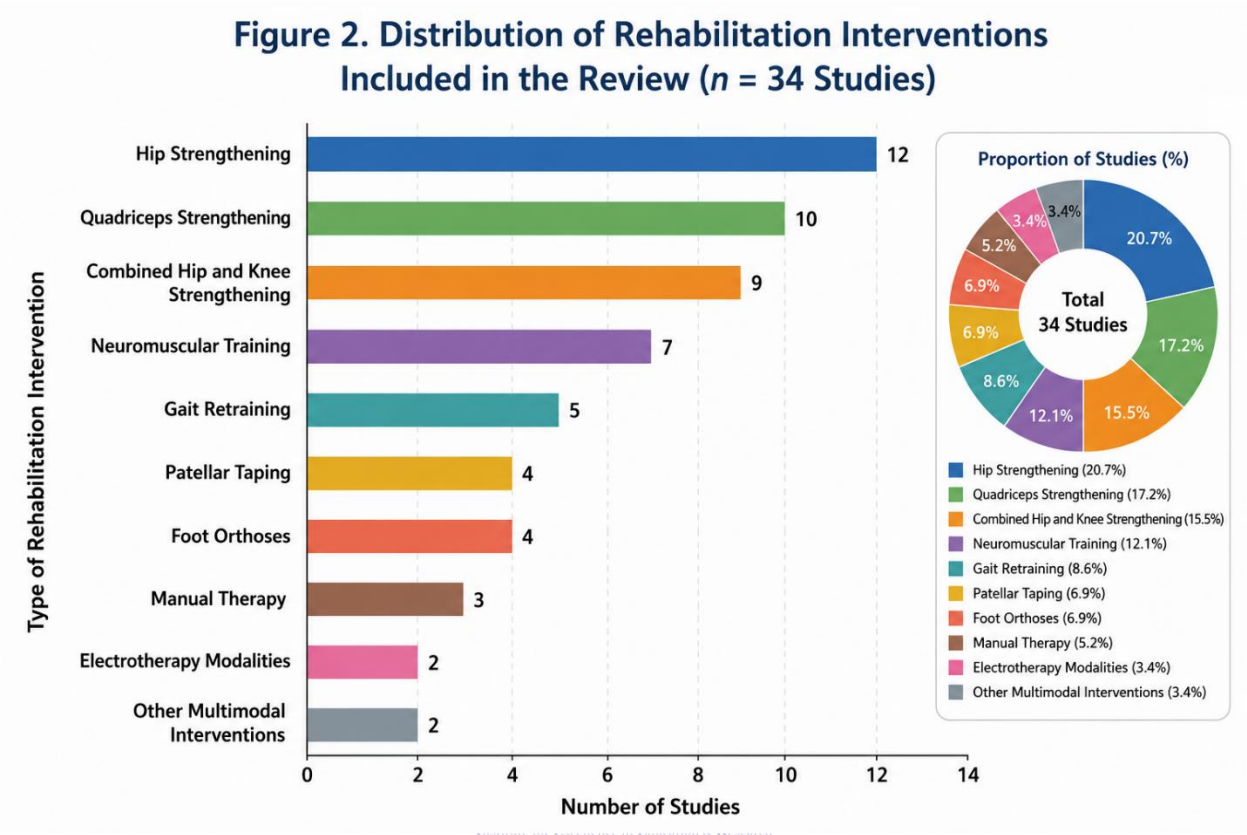

Figure 2. Distribution of rehabilitation interventions investigated across the included studies

DISCUSSION

This systematic review evaluated rehabilitation interventions for Patellofemoral Pain Syndrome (PFPS) published between 2015 and 2025 and synthesized current evidence regarding conservative physiotherapy management strategies. The findings demonstrate that exercise-based rehabilitation remains the most effective treatment approach for improving pain, functional performance, and lower limb biomechanics in individuals with PFPS. Among the included interventions, combined hip and knee strengthening programs consistently demonstrated the most favorable clinical outcomes across multiple randomized controlled trials and systematic reviews (6, 7, 11, 12, 15).

A major finding of this review was the superiority of combined proximal and local strengthening interventions over isolated quadriceps-focused rehabilitation. Earlier rehabilitation models for PFPS largely emphasized strengthening of the quadriceps musculature, particularly the vastus medialis oblique (VMO), based on theories of patellar mal-tracking and muscular imbalance (16). However, recent evidence increasingly supports the role of proximal biomechanical dysfunction in the development and persistence of PFPS (4). Weakness of the hip abductors, extensors, and external rotators contributes to excessive femoral internal rotation and dynamic knee valgus during weight-bearing activities, thereby increasing patellofemoral joint stress and abnormal loading patterns (5, 17).

The present review found that rehabilitation programs integrating hip strengthening with quadriceps exercises produced more consistent improvements in pain and function compared to isolated knee-focused interventions. Ferber et al.

reported clinically meaningful reductions in pain and improved lower extremity function following combined strengthening protocols targeting both hip and knee musculature (7). Similarly, Khayambashi et al. demonstrated that strengthening of the hip abductors and external rotators significantly improved pain intensity and functional performance in patients with PFPS (12). These findings support the concept that PFPS should be managed using a kinetic chain rehabilitation approach rather than focusing solely on local patellar mechanics.

Neuromuscular training and movement retraining interventions also demonstrated favorable clinical outcomes in the included studies. Abnormal movement patterns during squatting, landing, and running activities are known to increase patellofemoral joint loading and contribute to symptom persistence (2, 8). Several studies included in this review reported improvements in lower limb alignment, movement quality, and dynamic stability following neuromuscular rehabilitation programs. Esculier et al. demonstrated that gait retraining and neuromuscular control exercises improved running biomechanics and reduced patellofemoral stress in symptomatic runners (8). Similarly, Willy et al. reported that cadence retraining and correction of excessive hip adduction contributed to reductions in pain and improved running tolerance among athletes with PFPS (2).

The findings of the present review further emphasize the importance of individualized rehabilitation approaches. PFPS is considered a multifactorial condition influenced by muscular weakness, biomechanical impairments, altered movement patterns, training errors, and psychosocial contributors (2). Consequently, rehabilitation programs should be tailored according to patient-specific impairments rather than relying on standardized exercise protocols alone. Patients presenting with excessive dynamic valgus may benefit more from proximal strengthening and neuromuscular control training, whereas individuals with excessive foot pronation may require adjunctive foot orthoses and biomechanical correction strategies (6, 10).

Adjunctive rehabilitation interventions such as patellar taping and foot orthoses demonstrated moderate short-term effectiveness in symptom management. Patellar taping has been proposed to improve patellar alignment, reduce patellofemoral stress, and enhance proprioceptive feedback during functional activities (9). The included studies demonstrated that taping may provide temporary pain relief during stair climbing, squatting, and walking tasks, particularly when combined with exercise therapy. However, the long-term effectiveness of taping alone remains limited, and current evidence supports its use primarily as an adjunct to active rehabilitation rather than as a standalone treatment modality (18).

Similarly, foot orthoses demonstrated favorable outcomes in selected patients presenting with excessive pronation and altered lower extremity biomechanics. Collins et al. and Vicenzino et al. reported moderate improvements in pain and functional outcomes following orthotic intervention in individuals with PFPS (6, 10). Nevertheless, the effectiveness of orthoses appears to depend on patient-specific biomechanical characteristics, and universal prescription of orthotic devices cannot be recommended based on current evidence.

Another important finding of this review was the limited effectiveness of passive treatment modalities when used independently. Electrotherapy interventions including ultrasound therapy, transcutaneous electrical nerve stimulation (TENS), and neuromuscular electrical stimulation demonstrated inconsistent long-term outcomes across included studies (13). Although some investigations reported temporary symptom reduction, passive modalities generally failed to produce sustained improvements in function, biomechanics, or movement quality compared to exercise-based rehabilitation programs. Contemporary physiotherapy practice increasingly favors active rehabilitation approaches emphasizing patient participation, movement

correction, and progressive strengthening rather than passive symptom-modifying interventions.

The findings of this review are consistent with previous systematic reviews and clinical practice guidelines emphasizing the effectiveness of combined strengthening and movement-based rehabilitation strategies for PFPS management (2, 6). Crossley et al. and Willy et al. highlighted the importance of exercise therapy as the cornerstone of conservative PFPS management and recommended multimodal rehabilitation approaches targeting biomechanical impairments and muscular dysfunction (1, 6). The present review expands existing evidence by incorporating contemporary rehabilitation interventions published between 2015 and 2025, including gait retraining and neuromuscular control strategies that were less extensively represented in earlier reviews.

Despite the favorable findings reported across included studies, several methodological limitations within the literature should be acknowledged. Considerable heterogeneity existed in intervention protocols, exercise dosage, treatment duration, and outcome measures, limiting direct comparison between studies. Variability in participant characteristics, symptom chronicity, and activity level may also have influenced rehabilitation outcomes. Additionally, many studies demonstrated relatively short follow-up periods, limiting evaluation of long-term effectiveness and recurrence prevention.

Another limitation identified within the current evidence base is the lack of subgroup-specific rehabilitation approaches. Few studies classified participants according to biomechanical profiles, movement dysfunction patterns, or psychosocial contributors despite growing recognition of the multifactorial nature of PFPS. Future research should therefore prioritize individualized rehabilitation models integrating biomechanical assessment, movement analysis, and patient-reported outcome measures to optimize treatment effectiveness.

Overall, the findings of this systematic review support the implementation of multimodal rehabilitation programs integrating hip and knee strengthening, neuromuscular control exercises, gait retraining, and movement correction strategies for effective management of PFPS. Rehabilitation approaches targeting the entire lower extremity kinetic chain appear more beneficial than isolated local interventions and provide more consistent improvements in pain reduction, functional performance, and movement quality.

LIMITATIONS

Several limitations should be considered when interpreting the findings of this systematic review. First, heterogeneity existed among included studies regarding rehabilitation protocols, intervention duration, exercise intensity, and outcome measures, limiting direct comparison between studies. Second, only English-language studies were included, which may have introduced language bias. Third, a meta-analysis was not conducted because of methodological and clinical heterogeneity across interventions. Additionally, several included studies had relatively short follow-up durations, limiting evaluation of long-term rehabilitation outcomes. Variability in participant characteristics, including activity level and symptom chronicity, may also have influenced treatment outcomes.

RECOMMENDATIONS

The findings of this systematic review support the implementation of exercise-based rehabilitation as the primary conservative management approach for PFPS. Combined hip and knee strengthening programs should be prioritized because they consistently demonstrated favorable clinical outcomes in pain reduction and functional improvement. Rehabilitation programs should also incorporate neuromuscular training and movement retraining strategies to address dynamic lower limb dysfunction and abnormal movement patterns.

Adjunctive interventions such as patellar taping and foot orthoses may be considered for short-term symptom management in selected patients presenting with biomechanical impairments. Passive modalities including ultrasound and

electrical stimulation should not be used as isolated treatment approaches because current evidence demonstrates limited long-term effectiveness.

Future research should focus on large-scale randomized controlled trials with standardized rehabilitation protocols and long-term follow-up assessment. Additional investigation is also required to develop subgroup-specific rehabilitation strategies based on biomechanical and psychosocial characteristics.

CONCLUSION

This systematic review evaluated evidence published between 2015 and 2025 regarding rehabilitation interventions for Patellofemoral Pain Syndrome (PFPS). The findings indicate that exercise-based rehabilitation provides the most consistent clinical benefit for reducing pain and improving functional performance in individuals with PFPS. Combined hip and knee strengthening interventions demonstrated the most favorable outcomes across included studies, while neuromuscular training and gait retraining also contributed to improvements in lower limb biomechanics and movement quality. Adjunctive interventions such as patellar taping and foot orthoses may provide short-term symptomatic benefit when integrated within active rehabilitation programs. Current evidence supports an individualized multimodal rehabilitation approach addressing muscular strength deficits, biomechanical impairments, and movement dysfunction. Further high-quality research with standardized methodologies and longer follow-up periods is required to strengthen evidence-based rehabilitation guidelines for PFPS.

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