

# Emerging Physiotherapy and Rehabilitation Strategies for Patellofemoral Pain Syndrome: A Systematic Review

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## Abstract

Patellofemoral pain syndrome (PFPS) is a common musculoskeletal knee condition characterized by pain around or behind the patella, particularly during activities that increase patellofemoral joint loading. Its multifactorial nature and variation in clinical presentation make individualized physiotherapy management important. This systematic review aimed to synthesize evidence from randomized controlled trials evaluating contemporary physiotherapy interventions for improving pain, muscle strength, functional performance, balance, neuromuscular control, and biomechanical outcomes in individuals with PFPS.

A systematic literature search was conducted in PubMed/MEDLINE, PEDro (Physiotherapy Evidence Database), CINAHL (Cumulative Index to Nursing and Allied Health Literature), and Scopus for studies published from January 2021 to June 2026. Randomized controlled trials investigating physiotherapy and rehabilitation interventions for individuals with PFPS were eligible for inclusion. A total of 228 records were identified, 175 records were screened after removal of duplicates, and 42 full-text reports were assessed for eligibility. Finally, 18 randomized controlled trials were included in the systematic review.

The included studies investigated exercise therapy, strengthening, stretching, manual therapy, taping, proprioceptive training, electromyographic biofeedback, instrument-assisted soft-tissue mobilization, blood-flow-restriction training, foot-strike modification, balance or perturbation training, and foot orthoses. Across the included trials, beneficial effects were reported for selected outcomes including pain, muscle strength, functional performance, balance, neuromuscular control, and lower-limb biomechanics, although effects varied according to intervention, comparator, outcome, and assessment time point.

The findings suggest that exercise-based rehabilitation should remain a central component of physiotherapy management for PFPS, with adjunctive interventions selected according to individual impairments, functional limitations, and clinical presentation. However, heterogeneity in intervention protocols, outcome measures, sample sizes, and follow-up periods limits definitive conclusions regarding the comparative effectiveness of individual interventions. Further high-quality randomized controlled trials with standardized protocols and longer follow-up are required to determine the optimal combination of physiotherapy interventions for PFPS.

**Categories:** Pain Management, Quality Improvement, Healthcare Technology

**Keywords:** exercise therapy, functional performance, manual therapy, patellofemoral pain syndrome, strengthening exercises

## Introduction And Background

Patellofemoral pain syndrome (PFPS) is one of the most common musculoskeletal conditions affecting the knee and is characterized by pain around or behind the patella, particularly during activities such as squatting, stair climbing, running, jumping, and prolonged sitting. These activities increase patellofemoral joint loading, meaning the contact force between the patella and femur during movement, which may contribute to symptom provocation in individuals with PFPS. The condition commonly affects physically active individuals and can substantially interfere with daily activities, physical activity, and quality of life. Epidemiological evidence indicates that PFPS represents a considerable clinical burden across both adolescent and adult populations, highlighting the importance of effective assessment and management strategies [1].

The etiology of PFPS is considered multifactorial, involving interacting biomechanical, muscular, behavioral, and psychosocial factors rather than a single structural abnormality. Alterations in lower-limb biomechanics, muscle strength and function, movement patterns, and physical activity-related loading may contribute to the development or persistence of symptoms, although the strength and consistency of evidence vary across individual risk factors [2,3]. The term kinetic chain refers to the functional interaction of movements and forces across the trunk, hip, knee, and foot during lower-limb activities. Consequently, PFPS is increasingly viewed as a heterogeneous condition requiring individualized assessment rather than treatment based on a single presumed biomechanical abnormality [3,4].

Physiotherapy plays an important role in the management of PFPS, with exercise-based rehabilitation forming the core of contemporary conservative care. Exercise programs commonly target hip and knee

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muscle strength, flexibility, neuromuscular control, movement patterns, and functional capacity. International consensus recommendations support exercise therapy, particularly combined hip- and knee-focused programs, while adjunctive interventions such as foot orthoses, taping, and manual therapy may be incorporated according to individual patient presentation [5,6]. This individualized approach is supported by evidence showing beneficial effects of trunk-, hip-, and knee-focused rehabilitation on pain, functional performance, and muscle strength [7].

Despite the established role of exercise therapy, recent randomized controlled trials have investigated a broader range of physiotherapy strategies. These include manual therapy and stretching to improve joint or soft-tissue mobility; taping and foot orthoses to provide external mechanical support; proprioceptive, balance, and perturbation training to improve neuromuscular control; and gait or foot-strike retraining to modify movement patterns during walking or running. Other specialized approaches include instrument-assisted soft-tissue mobilization (IASTM), blood-flow-restriction (BFR) training, and electromyographic (EMG) biofeedback, which are intended to influence soft-tissue mobility, muscular loading, or neuromuscular activation, respectively. These approaches reflect an expanding physiotherapy evidence base but differ substantially in their proposed mechanisms, treatment dosage, target populations, and clinical outcomes, as shown in Figure 1.

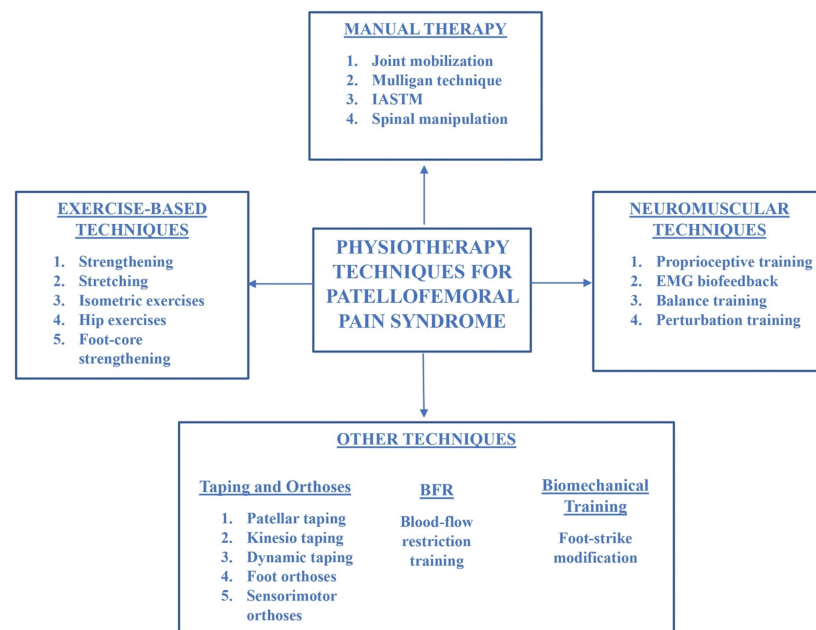


**FIGURE 1: Physiotherapy techniques for patellofemoral pain syndrome**

The figure was created using Microsoft PowerPoint (Microsoft Corporation, Redmond, Washington).

EMG: electromyography; IASTM: instrument-assisted soft tissue mobilization; BFR: blood-flow restriction.

Previous systematic reviews and international consensus statements have established the importance of exercise-based rehabilitation and have evaluated several commonly used physiotherapy interventions for PFPS. However, the evidence base continues to evolve, with newer randomized controlled trials evaluating emerging or specialized approaches such as BFR training, EMG biofeedback, IASTM, foot-strike modification, perturbation training, and different foot-orthosis and taping strategies. Recent trials have also used varied comparators and assessed a broad range of outcomes, including pain, functional performance, muscle strength, balance, gait, and lower-limb biomechanics. Therefore, an updated synthesis focused specifically on RCT evidence published from January 2021 through June 2026 provides an opportunity to capture recent intervention strategies and contemporary trial evidence while distinguishing sustained clinical outcomes from immediate or mechanistic findings. This approach complements earlier evidence syntheses by providing a focused assessment of the recent randomized evidence base rather than simply repeating established treatment recommendations.

Despite the expanding evidence base, substantial differences in intervention protocols, patient characteristics, comparators, treatment duration, follow-up, and outcome measures make it difficult to determine the relative effectiveness and clinical role of individual physiotherapy approaches. A contemporary synthesis is therefore warranted to clarify which interventions demonstrate improvements in pain and function, which primarily influence biomechanical or neuromuscular outcomes, and which may provide additional benefit when used alongside exercise-based rehabilitation.

## Review

### Methodology

#### Study Design

To ensure methodological rigor and transparent reporting, this systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines [8]. The review aimed to systematically identify, evaluate, and synthesize randomized controlled trials (RCTs) investigating physiotherapy, rehabilitation, and orthotic interventions for PFPS. The review protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO) under Registration No. CRD420261531931; however, the registration was completed retrospectively and therefore did not constitute prospective registration. Any methodological clarifications or deviations from the initial review plan were transparently reported where applicable. Risk of bias in the included RCTs was assessed using the Cochrane Risk of Bias 2 (RoB 2) tool [9]. Because of substantial clinical and methodological heterogeneity across the included studies in terms of interventions, comparators, participant characteristics, outcome measures, treatment dosage, and follow-up periods, findings were synthesized using a structured narrative approach rather than quantitative meta-analysis.

#### *Search Strategy*

A systematic literature search was conducted in PubMed/MEDLINE, PEDro (Physiotherapy Evidence Database), CINAHL, and Scopus. The final electronic searches were performed on August 20, 2026, with publication dates restricted to January 1, 2021, through June 30, 2026. Thus, June 30, 2026, represented the publication-date cutoff rather than the date of the final database search. The search strategy was designed to identify randomized controlled trials evaluating physiotherapy, rehabilitation, exercise, manual therapy, taping, proprioceptive, neuromuscular, biomechanical, and related interventions for PFP.

PubMed/MEDLINE was selected for broad biomedical and clinical indexing; PEDro was included because of its specific coverage of physiotherapy trials; CINAHL (Cumulative Index to Nursing and Allied Health Literature) provided allied-health and rehabilitation literature; and Scopus provided broad multidisciplinary and citation coverage. Gray literature, dissertations, conference proceedings, and unpublished studies were not systematically searched. Trial registries were not used as an independent source for identifying eligible unpublished studies. This limitation is acknowledged because potentially relevant unpublished or non-peer-reviewed evidence may therefore have been missed.

Backward reference-list screening was performed for all included studies and relevant systematic reviews identified during the screening process. The final reference-list screening was completed on August 20, 2026.

The following core concepts were used across databases: PFP/PFPS; physiotherapy/physical therapy/rehabilitation; exercise and strengthening; manual therapy; taping; proprioception and neuromuscular training; BFR exercise; biofeedback; soft-tissue techniques; foot orthoses; foot-strike modification; gait retraining; balance and perturbation training; and randomized controlled trials. The complete electronic search strategies and database-specific search details are summarized in Table 1.

| Database       | Search strategy                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Limits/filters                                                                                | Final search date |
|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|-------------------|
| PubMed/MEDLINE | ("Patellofemoral Pain"[Mesh] OR "patellofemoral pain"[tiab] OR "patellofemoral pain syndrome"[tiab] OR PFPS[tiab] OR "anterior knee pain"[tiab]) AND ("Physical Therapy Modalities"[Mesh] OR "Exercise Therapy"[Mesh] OR physiotherap[tiab] OR "physical therap[tiab] OR rehabilitation[tiab] OR "exercise therap[tiab] OR strengthening[tiab] OR "manual therap[tiab] OR taping[tiab] OR propriocept [tiab] OR "blood flow restriction" [tiab] OR BFR[tiab] OR "instrument-assisted soft tissue mobilization"[tiab] OR IASTM[tiab] OR biofeedback[tiab] OR stretching[tiab] OR "balance training"[tiab] OR "foot orthos"[tiab] OR "foot strike"[tiab] OR "gait retraining"[tiab] OR "perturbation training"[tiab]) AND (randomized controlled trial[pt] OR randomized[tiab] OR randomised[tiab] OR randomly[tiab] OR trial[tiab]) AND ("2021/01/01"[Date - Publication] : "2026/06/30"[Date - Publication]) AND Humans[Mesh] AND English[lang] | English; humans; publication date January 1, 2021-June 30, 2026; randomized controlled trials | August 20, 2026   |
| PEDro          | Advanced Search: Abstract & Title: patellofemoral pain syndrome; Method: Clinical trial; Subdiscipline: Musculoskeletal; Topic: Pain; Published since: 2021                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Clinical trials; musculoskeletal; pain; English; publications from 2021 through June 30, 2026 | August 20, 2026   |
| CINAHL (EBSCO) | (MH "Patellofemoral Pain Syndrome+" OR TI "patellofemoral pain" OR AB "patellofemoral pain" OR TI "patellofemoral pain syndrome" OR AB "patellofemoral pain syndrome" OR TI PFPS OR AB PFPS OR TI "anterior knee pain" OR AB "anterior knee pain") AND (MH "Physical Therapy+" OR MH "Exercise Therapy+" OR TI physiotherap OR AB physiotherap OR TI "physical therap" OR AB "physical therap" OR TI rehabilitation OR AB rehabilitation OR TI strengthening OR AB strengthening OR TI "manual therap" OR AB "manual therap" OR TI taping OR AB taping OR TI propriocept* OR AB propriocept* OR TI "blood flow restriction" OR AB "blood flow restriction" OR TI BFR OR AB BFR OR TI biofeedback OR AB biofeedback OR TI stretching OR AB stretching OR TI "balance training" OR AB "balance training" OR TI "gait retraining" OR AB "gait retraining") AND (TI random OR AB random OR TI trial OR AB trial)                                    | English; human; publication date January 1, 2021-June 30, 2026                                | August 20, 2026   |
| Scopus         | TITLE-ABS-KEY(("patellofemoral pain" OR "patellofemoral pain syndrome" OR PFPS OR "anterior knee pain") AND (physiotherap OR "physical therap" OR rehabilitation OR "exercise therap" OR strengthening OR "manual therap" OR taping OR propriocept OR "blood flow restriction" OR BFR OR "instrument-assisted soft tissue mobilization" OR IASTM OR biofeedback OR stretching OR "balance training" OR "foot orthos" OR "foot strike" OR "gait retraining" OR "perturbation training") AND (random* OR trial)) AND PUBYEAR > 2020 AND PUBYEAR < 2027 AND LANGUAGE = "English"                                                                                                                                                                                                                                                                                                                                                                   | English; publication year 2021-2026; randomized/trial terminology                             | August 20, 2026   |

**TABLE 1: Search strategy**

AB: abstract; BFR: blood flow restriction; CINAHL: Cumulative Index to Nursing and Allied Health Literature; EBSCO: Elton B. Stephens Company; IASTM: instrument-assisted soft tissue mobilization; MeSH: Medical Subject Headings; MH: CINAHL Subject Heading; PFPS: patellofemoral pain syndrome; PEDro: Physiotherapy Evidence Database; TI: title.

#### Eligibility Criteria

**Inclusion criteria:** Studies were included if they investigated human participants diagnosed with PFP or PFPS and evaluated a physiotherapy or rehabilitation intervention, including exercise therapy, strengthening, stretching, manual therapy, taping, proprioceptive training, BFR training, IASTM, biofeedback, gait or foot-strike retraining, or foot orthoses. Eligible studies were randomized controlled trials published in English between January 2021 and June 2026 and were required to include an appropriate comparator and report relevant clinical or functional outcomes such as pain, muscle strength, functional performance, balance, flexibility, biomechanics, or neuromuscular control.

**Exclusion criteria:** Studies were excluded when participants did not have PFP/PFPS or when another primary knee condition, such as ACL injury, meniscal injury, knee osteoarthritis, patellar tendinopathy, or fracture, was investigated. Studies evaluating pharmacological or surgical interventions without a physiotherapy component were excluded. Case reports, case series, observational studies, reviews, systematic reviews, meta-analyses, editorials, protocols, and other non-randomized designs were also excluded. Non-English publications, animal or cadaver studies, studies without an appropriate comparator, studies lacking relevant clinical or functional outcomes, and studies published outside the specified period were excluded, as shown in Table 2.

| Criteria           | Inclusion criteria                                                                                                                                                                                                                      | Exclusion criteria                                                                                                      |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| Participants       | Individuals diagnosed with patellofemoral pain syndrome/PFPS                                                                                                                                                                            | Participants without PFPS/PFP or populations with other primary knee conditions                                         |
| Condition          | Patellofemoral pain or patellofemoral pain syndrome                                                                                                                                                                                     | ACL injury, meniscal injury, osteoarthritis, patellar tendinopathy, fracture, or other primary knee disorders           |
| Intervention       | Physiotherapy and rehabilitation interventions, including exercise therapy, strengthening, stretching, manual therapy, taping, proprioceptive training, BFR, IASTM, biofeedback, gait/foot-strike retraining, and related interventions | Pharmacological or surgical interventions without a physiotherapy component                                             |
| Comparator         | Conventional physiotherapy, another physiotherapy intervention, placebo/sham intervention, or control group                                                                                                                             | Studies without an appropriate comparator                                                                               |
| Study design       | Randomized controlled trials                                                                                                                                                                                                            | Case reports, case series, observational studies, reviews, systematic reviews, meta-analyses, editorials, and protocols |
| Language           | English-language studies                                                                                                                                                                                                                | Non-English studies                                                                                                     |
| Outcomes           | Pain, functional performance, muscle strength, balance, flexibility, biomechanics, neuromuscular control, or related clinical outcomes                                                                                                  | Studies not reporting relevant clinical or functional outcomes                                                          |
| Population         | Human participants                                                                                                                                                                                                                      | Animal or cadaver studies                                                                                               |
| Publication period | January 2021 to June 2026                                                                                                                                                                                                               | Studies published outside the specified period                                                                          |

**TABLE 2: Eligibility criteria of the included studies**

PFPS: patellofemoral pain syndrome; PFP: patellofemoral pain; BFR: blood flow restriction; IASTM: instrument-assisted soft-tissue mobilization; RCT: randomized controlled trial; ACL: anterior cruciate ligament.

#### Study Selection

Titles and abstracts were screened independently by two reviewers against the predefined eligibility criteria, followed by independent full-text assessment of potentially relevant reports. Any disagreements or uncertainties regarding study eligibility were resolved through discussion and consensus, with a third reviewer consulted when consensus could not be reached.

#### Data Extraction

Data were extracted independently by two reviewers using a standardized, predefined data-extraction form developed for this review. Extracted information included author and publication year, study design, participant characteristics, sample size, diagnostic criteria, intervention and comparator details, treatment duration and frequency, outcome measures and assessment time points, adherence, dropout or withdrawals, adverse events, co-interventions, protocol deviations, and main numerical findings. Discrepancies between reviewers were resolved through discussion and consensus, with a third reviewer consulted when consensus could not be reached.

#### Outcome Measures

Outcomes were grouped into four domains: clinical, functional, muscular/neuromuscular, and biomechanical outcomes. Clinical outcomes primarily included pain intensity measured using the Visual Analog Scale (VAS) or Numeric Pain Rating Scale (NPRS), while functional outcomes included patient-reported measures such as the Kujala Anterior Knee Pain Scale (AKPS). The AKPS has demonstrated reliability and validity for assessing knee-related pain and function [10], and the VAS has established validity for pain assessment [11]. Muscular/neuromuscular outcomes included strength, muscle activation, balance, and proprioception, while biomechanical outcomes included alignment, gait, kinematics, and ground-reaction forces.

#### Quality Assessment

Risk of bias was assessed independently by two reviewers using the RoB 2 tool for randomized controlled trials. The assessment considered five domains: bias arising from the randomization process; bias due to deviations from intended interventions; bias due to missing outcome data; bias in measurement of the outcome; and bias in selection of the reported result. The RoB 2 signaling questions and corresponding decision algorithm were used to support domain-level judgments.

Risk of bias was assessed for the specific outcome and time point contributing to the synthesis, rather than assigning a single generic judgment to each study irrespective of outcome or follow-up. The assessment

targeted the effect of assignment to the randomized intervention rather than the effect of adherence to the intervention. Disagreements between reviewers were resolved through discussion and consensus, with a third reviewer consulted when consensus could not be reached.

Overall judgments were derived according to the RoB 2 framework from the domain-level judgments for each assessed result. Results with all domains judged low risk were classified as low risk, whereas results with one or more domains raising concerns that did not meet the criteria for high risk were classified as having some concerns. A high-risk judgment was assigned when the RoB 2 criteria indicated high risk in one or more domains or when the overall pattern of concerns warranted such a judgment [9].

Data Synthesis

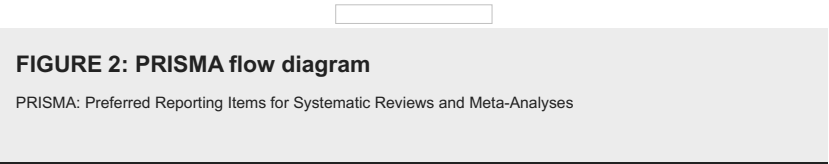
A structured narrative synthesis was performed because the included trials demonstrated substantial heterogeneity in intervention types, treatment protocols, comparators, participant characteristics, outcome measures, and assessment time points. The interventions were grouped into clinically meaningful categories, including exercise-based rehabilitation, manual and soft-tissue interventions, taping and foot orthoses, neuromuscular and balance interventions, biomechanical and gait retraining, and specialized interventions such as BFR and EMG biofeedback.

Findings were synthesized according to intervention type, comparator, outcome domain, and follow-up period. Where studies compared an adjunctive intervention with the same underlying exercise program, the findings were interpreted as add-on effects; head-to-head comparisons were interpreted separately from comparisons with placebo, sham, or no intervention. Immediate biomechanical or neuromuscular outcomes were distinguished from longer-term clinical outcomes such as pain and functional performance.

A quantitative meta-analysis was not performed because the substantial clinical and methodological heterogeneity across the included trials limited the appropriateness of statistically pooling the results. Differences in intervention dosage, comparator conditions, participant populations, outcome instruments, and follow-up periods would have resulted in pooled estimates with limited clinical interpretability. Therefore, a structured narrative synthesis was considered more appropriate for summarizing the available evidence.

Results

The database searches identified 228 records. After removal of 53 duplicate records, 175 records were screened by title and abstract, of which 128 were excluded. Forty-seven reports were sought for full-text retrieval; five reports could not be retrieved and were therefore not assessed for eligibility. The remaining 42 reports were assessed against the predefined eligibility criteria, and 24 were excluded after full-text assessment for reasons including wrong study design, wrong population, wrong intervention or comparator, duplicate or secondary publication, and insufficiently relevant outcome data. The five non-retrieved reports were not included among the 24 full-text exclusions. A total of 18 randomized controlled trials met the eligibility criteria and were included in the systematic review. The study-selection process is presented in the revised PRISMA 2020 flow diagram (Figure 2).



Characteristics of Included Studies

The present systematic review included 18 randomized controlled trials evaluating a broad range of physiotherapy, rehabilitation, and orthotic interventions for PFPS. The interventions included manual therapy, stretching, strengthening, proprioceptive training, taping, EMG biofeedback, IASTM, BFR training, spinal manipulation, foot-strike modification, balance and perturbation training, and foot orthoses. Participant characteristics, diagnostic criteria, intervention and comparator details, treatment duration and frequency, follow-up, outcome measures, adherence, dropout or withdrawals, adverse events, co-interventions, protocol deviations, and reported numerical findings are summarized in Table 3.

The included studies varied substantially in sample size, participant characteristics, intervention dosage, comparator conditions, and outcome assessment time points. Several trials specifically recruited young adults, athletes, female participants, or female runners, whereas others included broader adult populations with PFPS. Where participant characteristics, adherence, adverse events, or numerical outcome data were not sufficiently reported in the original publications, these items are identified as “NR” (not reported) in Table 3.

| Author (year) | Study design | Participants: age/sex | Diagnostic criteria/baseline characteristics | Intervention | Comparator | Duration/frequency | Outcomes and assessment time point | Main findings according to study | Main numerical findings | Adherence/dropout | Adverse events |
|---------------|--------------|-----------------------|----------------------------------------------|--------------|------------|--------------------|------------------------------------|----------------------------------|-------------------------|-------------------|----------------|
|               |              |                       |                                              |              |            |                    |                                    | Tibiofemoral mobilization        | Significant             |                   | Adverse e      |

|                                      |                                                     |                                                                             |                                                                             |                                                                      |                                                |                                              |                                                                                           |                                                                                                                                          |                                                                                                                                                   |                            |                                                               |
|--------------------------------------|-----------------------------------------------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------|----------------------------------------------------------------------|------------------------------------------------|----------------------------------------------|-------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|---------------------------------------------------------------|
| Fatimah et al. (2021) [12]           | Randomized controlled trial                         | n = 52; 26/26; 25-35 years; sex: NR                                         | Clinically diagnosed PFPS; baseline severity: NR                            | Tibiofemoral mobilization + conventional exercise                    | Conventional exercise                          | 4 weeks; 3 sessions/week                     | Pain and functional status; baseline and post-intervention                                | showed beneficial effects in patients with PFPS.                                                                                         | Improvement in pain and function reported; exact between-group values: NR                                                                         | Adherence: NR; dropout: NR | co-interventive protocol deviations                           |
| Lee et al. (2021) [13]               | Randomized controlled trial                         | n = 44 analyzed; male/female 7/13 vs 8/16                                   | PFPS with inflexible quadriceps; symptom duration 3.8±2.1 vs 4.1±1.6 months | Static quadriceps stretching                                         | Dynamic quadriceps stretching                  | 6-month intervention protocol; frequency: NR | Quadriceps flexibility, strength, activation time and patient-reported outcomes; pre/post | Both static and dynamic quadriceps stretching were investigated for their effects on clinical outcomes in patients with PFPS.            | No significant differences after intervention (P > 0.05); post-intervention flexibility 128±2.6° vs 126 ± 7.9°; strength 165 ± 49.1 vs 183 ± 46.5 | Adherence: NR; dropout: NR | Adverse effects; co-interventive protocol deviations          |
| da Silva Boltrago et al. (2021) [14] | Randomized controlled trial                         | n = 60; females; age: NR                                                    | Clinically diagnosed PFPS; baseline severity: NR                            | Resisted/proprioceptive exercise for trunk, hip and knee musculature | Educational, cognitive and behavioral guidance | 6 weeks; frequency: NR                       | NPRS, AKPS, KOS-ADLS, isometric strength and 2D biomechanics; pre/post                    | The combined proprioceptive and strengthening program improved pain and functionality in women with PFPS.                                | Significant improvement in NPRS, AKPS, and KOS-ADLS in the exercise group (ps0.05)                                                                | Adherence: NR; dropout: NR | Adverse effects; co-interventive protocol deviations          |
| Hasan et al. (2022) [15]             | Randomized controlled trial                         | n = 60; 30/30; young adult male athletes; mean age approximately 26.9 years | PFPS; baseline VAS approximately 7.0 ± 0.7 vs 6.8 ± 0.7                     | Patellar taping + EMG-biofeedback-guided quadriceps exercise         | Sham taping + exercise without EMG biofeedback | 6 weeks                                      | Pain, AKPS/function, quadriceps strength and single-leg triple hop; baseline/week 6       | Patellar taping combined with EMG biofeedback was effective for improving quadriceps strength and functional performance.                | Week-6 pain: 1.3 ± 0.8 vs 4.5 ± 0.8; AKPS: 80.4 ± 5.1 vs 69.1 ± 6.1; SLTH: 540.7 ± 51.2 vs 509.4 ± 49.8; between-group ps0.001                    | Adherence: NR; dropout: NR | Adverse effects; co-interventive exercise protocol deviations |
| Anwar et al. (2022) [16]             | Randomized controlled trial                         | n = 45; 3 groups, 15/group; age/sex: NR                                     | PFPS; baseline pain/function: NR                                            | Mulligan pain-release phenomenon + conventional treatment            | Conventional treatment/control groups          | NR                                           | Pain and functional outcomes; pre/post                                                    | The Mulligan pain-release phenomenon technique demonstrated beneficial effects in the management of PFPS.                                | Improvement in pain and function reported; exact numerical results: NR                                                                            | Adherence: NR; dropout: NR | Adverse effects; co-interventive protocol deviations          |
| Kim et al. (2022) [17]               | Single-blind, three-arm randomized controlled trial | n = 48; 16/16/16; age/sex: NR                                               | PFPS; baseline pain, function and foot characteristics: NR                  | Talonavicular joint mobilization                                     | Foot-core strengthening/combined intervention  | NR                                           | Pain, function and foot-related outcomes; pre/post                                        | Talonavicular mobilization and foot-core strengthening demonstrated beneficial effects on PFPS-related clinical and functional outcomes. | Between-group numerical results: NR                                                                                                               | Adherence: NR; dropout: NR | Adverse effects; co-interventive protocol deviations          |
| Liu et al. (2023) [18]               | Randomized controlled trial                         | n = 26; 13/13; age/sex: NR                                                  | Patellofemoral joint pain/PFPS; baseline pain, function and strength: NR    | IASTM + BFR training                                                 | IASTM alone                                    | NR                                           | Pain, function and muscle strength; pre/post                                              | Combined IASTM and BFR training improved pain, function, and muscle strength in individuals with patellofemoral joint pain.              | Additional improvement reported with combined IASTM+BFR; exact numerical values: NR                                                               | Adherence: NR; dropout: NR | Adverse effects; co-interventive IASTM as protocol deviations |
| Both hip                             |                                                     |                                                                             |                                                                             |                                                                      |                                                |                                              |                                                                                           |                                                                                                                                          |                                                                                                                                                   |                            |                                                               |

|                          |                                                   |                                                         |                                                               |                                                                       |                                                        |                        |                                                                                         |                                                                                                                                                                                                 |                                                                                                              |                                                                  |                                                                     |
|--------------------------|---------------------------------------------------|---------------------------------------------------------|---------------------------------------------------------------|-----------------------------------------------------------------------|--------------------------------------------------------|------------------------|-----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|---------------------------------------------------------------------|
| Raju et al. (2024) [19]  | Randomized controlled trial                       | n = 45; 3 groups; 15/group; age/sex: NR                 | PFPS; baseline pain/function: NR                              | Hip abductor + external rotator strengthening/proprioceptive training | Proprioceptive or conventional comparison intervention | NR                     | Pain and functional outcomes; pre/post                                                  | strengthening and proprioceptive training were evaluated for their effects on pain and function in patients with PFPS.                                                                          | Significant improvements reported; exact between-group values: NR                                            | Adherence: NR; dropout: NR                                       | Adverse effects: co-intervention protocol d                         |
| Simon et al. (2025) [20] | Randomized controlled clinical trial              | n = 26; 13/13; age/sex: NR                              | PFPS; biomechanical/plantar-pressure characteristics assessed | Biomechanical foot orthoses (BMFO)                                    | Sensorimotor foot orthoses (SMFO)                      | 3 months               | Pain, AKPS, VAS and plantar pressure; baseline/post-intervention                        | Both biomechanical and sensorimotor foot orthoses were associated with significant reductions in knee pain over 3 months. No significant difference in pain reduction was found between groups. | Both orthotic interventions reduced pain; no clear between-group superiority reported; exact values: NR      | Adherence: NR; dropout: NR                                       | Adverse effects: co-intervention protocol d                         |
| Hasan et al. (2025) [21] | Randomized comparative study                      | n = 60; 30/30; adult females; age: NR                   | PFPS; baseline pain, strength and function: NR                | Patellar taping + quadriceps isometric strengthening at 60°           | Placebo taping + same strengthening                    | 6 weeks                | Pain, quadriceps strength and functional performance; baseline/week 6                   | Combining patellar taping with isometric strengthening was associated with improvements in pain, muscle strength, and functional performance.                                                   | Significant improvements in pain, strength and function reported; exact numerical values: NR                 | Adherence: NR; dropout: NR                                       | Adverse effects: co-intervention isometric : as specific deviations |
| Abdo et al. (2025) [22]  | Double-blind randomized controlled clinical trial | n = 59; 29 intervention/30 control; adults; age/sex: NR | PFPS; baseline pain/function/muscle measures: NR              | Manual therapy + hip/knee exercises                                   | Hip/knee exercises                                     | NR                     | Pain, function and muscle outcomes; pre/post                                            | Adding manual therapy to hip and knee exercises demonstrated additional benefits for patients with PFPS.                                                                                        | Additional benefit reported with manual therapy; exact between-group values: NR                              | Adherence: NR; dropout: 1 participant                            | Adverse effects: co-intervention hip/knee : specified; deviations   |
| Won et al. (2025) [23]   | Randomized controlled trial                       | n = 30; 15/15; age/sex: NR                              | PFPS; baseline pain and quadriceps strength: NR               | Lumbar spinal manipulation                                            | Placebo manipulation                                   | NR                     | Pain, quadriceps strength, proprioception and dynamic balance; immediate/post-treatment | Lumbar spinal manipulation was investigated for its effects on pain and quadriceps strength in patients with PFPS.                                                                              | Pain reduction and increased quadriceps strength reported; minimal changes in proprioception/dynamic balance | Adherence: NR; dropout: NR                                       | Adverse effects: co-intervention protocol d                         |
| Cho et al. (2025) [24]   | Randomized controlled study                       | n = 28; 14/14; female runners; age: NR                  | PFPS; baseline pain/function: NR                              | IASTM targeting hip and knee                                          | IASTM targeting knee alone                             | Immediate intervention | Pain and functional outcomes; immediate post-intervention                               | IASTM produced immediate effects on pain and functional outcomes in female runners with PFPS.                                                                                                   | Immediate changes in pain/function reported; exact numerical values: NR                                      | Adherence: Not applicable to immediate intervention; dropout: NR | Adverse effects: co-intervention protocol d                         |

AKPS: Anterior Knee Pain Scale; BFR: blood flow restriction; BMFO: biomechanical foot orthoses; EMG: electromyography; GMax: gluteus maximus; GMed: gluteus medius; GRF: ground-reaction force; IASTM: instrument-assisted soft tissue mobilization; KOS-ADLS: Knee Outcome Survey-Activities of Daily Living Scale; NR: not reported; NPRS: Numeric Pain Rating Scale; PFP: patellofemoral pain; PFPS: patellofemoral pain syndrome; SLTH: single-leg triple hop; SMFO: sensorimotor foot orthoses; VAS: Visual Analog Scale.

### *Participant Characteristics*

The included trials evaluated heterogeneous patient populations, including young adults, athletes, female participants, and female runners. Most studies involved adults with clinically diagnosed PFPS or PFP, although diagnostic criteria and baseline clinical characteristics varied across trials. Several studies did not fully report age, symptom duration, baseline severity, or other potentially relevant clinical characteristics. Findings from athlete- or runner-specific populations were therefore interpreted separately from evidence derived from broader PFPS populations.

### *Intervention-Specific Synthesis*

**Core exercise-based rehabilitation:** Exercise-based interventions included strengthening, stretching, proprioceptive exercise, and hip-, knee-, and trunk-focused programs. These interventions provided the broadest evidence for improvements in pain, muscle function, and physical function. However, differences in exercise content, dosage, comparator conditions, and outcome measures prevented determination of a single optimal exercise program.

**Manual and soft-tissue interventions:** Manual and soft-tissue interventions included tibiofemoral and talonavicular joint mobilization, Mulligan techniques, manual therapy, IASTM, and lumbar spinal manipulation. These interventions demonstrated short-term or outcome-specific effects, with some studies reporting additional benefits when manual techniques were combined with exercise. Immediate findings from IASTM and spinal manipulation should be distinguished from effects observed following longer treatment periods, as the available evidence does not establish whether such short-term effects are sustained.

**Taping and foot orthoses:** Patellar, dynamic, and Kinesio taping demonstrated improvements in selected clinical, functional, balance, and biomechanical outcomes, although the direction and magnitude of effects varied according to the comparator and assessment time point. Foot orthoses were primarily evaluated through head-to-head comparisons and were associated with improvements in pain and lower-limb kinematic outcomes, without clear evidence that one orthotic design was consistently superior to another. These findings support consideration of taping and orthoses as individualized adjunctive options rather than universally superior interventions.

**Neuromuscular and balance interventions:** Proprioceptive, EMG-biofeedback, balance, and perturbation interventions primarily targeted quadriceps activation, balance, muscle activity, and neuromuscular control. The included trials demonstrated improvements in selected neuromuscular, functional, and biomechanical outcomes. However, these findings were based on relatively few trials with heterogeneous intervention protocols and outcome measures.

**Biomechanical and gait retraining:** Biomechanical and gait-focused approaches, including altered foot-strike training, primarily targeted lower-limb alignment, gait mechanics, and movement patterns. These interventions produced changes in selected biomechanical outcomes; however, the available evidence is insufficient to determine whether such changes consistently translate into sustained reductions in pain or improvements in functional outcomes.

**Specialized interventions:** Specialized approaches, particularly BFR training and EMG biofeedback, provided emerging evidence for improvements in muscle function and strength. However, these interventions were evaluated in a limited number of trials involving specific populations and treatment protocols. Their findings should therefore be interpreted cautiously and should not be considered evidence of universal clinical superiority.

Overall, the findings demonstrated that treatment effects were intervention- and outcome-specific. No single physiotherapy or orthotic intervention could be considered universally superior across the heterogeneous PFPS populations and clinical outcomes evaluated in the included trials.

### *Comparator-Specific Synthesis*

The clinical interpretation of treatment effects differed according to the comparator used in each trial. Add-on comparisons, such as manual therapy or other adjunctive interventions combined with exercise versus exercise alone, evaluated whether the additional intervention provided benefit beyond the underlying exercise program. Head-to-head comparisons evaluated differences between two active interventions and therefore did not establish superiority over no treatment. Placebo- or sham-controlled trials assessed effects beyond those associated with the control procedure or treatment context, whereas no-intervention comparisons evaluated the effect of an active intervention relative to the absence of active treatment.

These comparator types were therefore not considered equivalent. Findings were interpreted within the context of the specific comparison, outcome domain, and assessment time point. Immediate post-intervention changes in pain, balance, muscle activation, ground-reaction forces, or kinematics were distinguished from outcomes assessed after several weeks of treatment or follow-up. This approach was used to avoid interpreting immediate or mechanistic changes as evidence of sustained clinical effectiveness.

### *Risk of Bias Assessment*

Risk of bias was assessed independently by two reviewers for the relevant outcomes and time points using the RoB 2 tool. Disagreements were resolved through discussion and consensus, with a third reviewer consulted when consensus could not be reached.

Among the 18 included randomized controlled trials, two were judged to have a low overall risk of bias, and 16 were judged to have some concerns; no assessed result was judged to have a high overall risk of bias. The domain-level assessment identified concerns most frequently in the randomization process, deviations from intended interventions, and measurement of outcomes. These concerns were interpreted according to the RoB 2 signaling questions and decision algorithm and were not classified as high risk solely because participants or therapists could not be blinded, which may be inherent to physiotherapy interventions. Some studies also had incomplete reporting of methodological procedures, resulting in some concerns where the available information was insufficient to support a low-risk judgment.

Risk-of-bias judgments were made for the specific outcomes and time points contributing to the synthesis rather than assigning a single generic judgment to each study. The assessment therefore reflects the risk of bias for the reported results included in the review. The distribution of judgments across the five RoB 2 domains is summarized in Table 4.

| Study number | Study                         | D1: randomization | D2: Deviations from intended interventions | D3: Missing outcome data | D4: Measurement of outcome | D5: Selection of reported result | Overall ROB   |
|--------------|-------------------------------|-------------------|--------------------------------------------|--------------------------|----------------------------|----------------------------------|---------------|
| 1            | Fatimah et al. [12]           | Some concerns     | Some concerns                              | Low risk                 | Some concerns              | Low risk                         | Some concerns |
| 2            | Lee et al. [13]               | Low risk          | Some concerns                              | Low risk                 | Low risk                   | Low risk                         | Some concerns |
| 3            | da Silva Boitrigo et al. [14] | Some concerns     | Some concerns                              | Low risk                 | Low risk                   | Low risk                         | Some concerns |
| 4            | Hasan et al. [15]             | Some concerns     | Some concerns                              | Low risk                 | Some concerns              | Low risk                         | Some concerns |
| 5            | Anwar et al. [16]             | Low risk          | Some concerns                              | Low risk                 | Some concerns              | Low risk                         | Some concerns |
| 6            | Kim et al. [17]               | Low risk          | Some concerns                              | Low risk                 | Some concerns              | Low risk                         | Some concerns |
| 7            | Liu et al. [18]               | Some concerns     | Some concerns                              | Low risk                 | Some concerns              | Low risk                         | Some concerns |
| 8            | Raju et al. [19]              | Low risk          | Some concerns                              | Low risk                 | Low risk                   | Low risk                         | Some concerns |
| 9            | Simon et al. [20]             | Some concerns     | Some concerns                              | Low risk                 | Some concerns              | Low risk                         | Some concerns |
| 10           | Hasan et al. [21]             | Some concerns     | Some concerns                              | Low risk                 | Some concerns              | Low risk                         | Some concerns |
| 11           | Abdo et al. [22]              | Low risk          | Low risk                                   | Some concerns            | Low risk                   | Low risk                         | Some concerns |
| 12           | Won et al. [23]               | Low risk          | Some concerns                              | Low risk                 | Low risk                   | Low risk                         | Some concerns |
| 13           | Cho et al. [24]               | Some concerns     | Some concerns                              | Low risk                 | Some concerns              | Low risk                         | Some concerns |
| 14           | Yalfani et al. [25]           | Low risk          | Low risk                                   | Low risk                 | Low risk                   | Low risk                         | Low risk      |
| 15           | Simon et al. [26]             | Some concerns     | Some concerns                              | Low risk                 | Some concerns              | Low risk                         | Some concerns |
| 16           | Yalfani et al. [27]           | Low risk          | Some concerns                              | Low risk                 | Some concerns              | Low risk                         | Some concerns |
| 17           | Lee et al. [28]               | Low risk          | Low risk                                   | Some concerns            | Low risk                   | Low risk                         | Some concerns |
| 18           | Zare Bidoki et al. [29]       | Low risk          | Low risk                                   | Low risk                 | Low risk                   | Low risk                         | Low risk      |

**TABLE 4: Risk of bias assessment of randomized controlled trials using Cochrane the Risk of Bias 2 (RoB 2) tool.**

ROB: risk of bias.

## Discussion

The present systematic review synthesized evidence from 18 randomized controlled trials (RCTs) evaluating different rehabilitation approaches for PFPS. Because the interventions differed in mechanism, dosage, comparator, and outcome assessment, the findings were interpreted according to clinically meaningful intervention categories rather than as a single treatment group. The included evidence comprised exercise-based rehabilitation, manual and soft-tissue techniques, taping and foot orthoses, neuromuscular and balance interventions, biomechanical or gait retraining, and specialized interventions such as blood-flow restriction (BFR) and EMG biofeedback.

### *Core Exercise-Based Rehabilitation*

Exercise-based interventions provided the broadest evidence across the included studies. Fatimah et al. reported improvements in pain and functional status following tibiofemoral mobilization combined with conventional exercise [12], while Lee et al. demonstrated clinical changes following both static and dynamic quadriceps stretching [13]. da Silva Boitrage et al. reported improvements in pain and function following proprioceptive exercise combined with strengthening [14]. Kim et al. found beneficial clinical and functional effects with talonavicular mobilization combined with foot-core strengthening [17], and Raju et al. reported improvements following hip abductor and external rotator strengthening and proprioceptive training [19]. These findings support progressive strengthening and functional exercise as the foundation of PFPS rehabilitation. However, because several trials combined exercise with additional interventions, the independent effect of strengthening cannot always be separated from the effect of the adjunct.

#### *Manual and Soft-Tissue Interventions*

Manual and soft-tissue techniques demonstrated more specific or adjunctive effects. Fatimah et al. reported beneficial effects of tibiofemoral mobilization [12], and Anwar et al. reported favorable pain and functional outcomes following the Mulligan pain-release phenomenon technique [16]. Abdo et al. found additional benefits when manual therapy was added to hip and knee exercises compared with exercise alone [22], supporting an add-on effect rather than suggesting that manual therapy should replace active rehabilitation. Liu et al. reported improvements following combined IASTM and BFR [18], whereas Cho et al. reported immediate or short-term changes following IASTM [24]. Won et al. evaluated lumbar spinal manipulation and reported changes in pain and quadriceps strength [23]. These studies represent different manual or soft-tissue approaches and comparators; therefore, their findings should not be interpreted as evidence of a uniform effect or pooled clinically as equivalent interventions.

#### *Taping and Foot Orthoses*

External supports demonstrated outcome-specific effects across the included trials. Hasan et al. reported improvements in quadriceps strength and functional performance when patellar taping was combined with EMG biofeedback [15]. Similarly, Hasan S et al. reported improvements in pain, quadriceps strength, and functional performance when patellar taping was combined with isometric strengthening compared with placebo taping and the same strengthening program [21]. Yalfani et al. reported immediate changes in balance and ground-reaction-force parameters following dynamic and Kinesio taping [27]. These findings suggest potential short-term neuromuscular and biomechanical effects of taping; however, the immediate nature of some outcomes and differences in intervention protocols limit conclusions regarding sustained clinical effectiveness.

Foot orthoses were primarily evaluated through head-to-head comparisons. Simon et al. reported reductions in perceived knee pain with both biomechanical foot orthoses (BMFOs) and sensorimotor foot orthoses (SMFOs), with no clear evidence that either approach was superior [20]. In a separate study, Simon et al. reported changes in ankle and knee kinematic parameters following both orthotic approaches [26]. These findings suggest that different orthotic designs may influence pain and lower-limb biomechanics in individuals with PFPS; however, the available evidence does not establish one orthotic design as universally superior. Their use may therefore be considered an individualized adjunctive option when relevant biomechanical characteristics or clinical needs are identified.

#### *Neuromuscular, Balance, and Biomechanical Interventions*

Neuromuscular and biomechanical interventions primarily targeted movement control rather than pain alone. Hasan et al. reported improvements with EMG biofeedback combined with patellar taping [15], while Zare Bidoki et al. reported effects of balance and perturbation training on gluteal muscle activity and hip kinematics [29]. Yalfani A et al. found that altered foot-strike training combined with lower-extremity strengthening improved lower-limb alignment [25]. These findings suggest that neuromuscular and gait-based interventions may be relevant when specific deficits in balance, proximal control, or movement patterns are identified. However, improvements in muscle activation, alignment, or kinematic variables should not automatically be interpreted as sustained improvements in pain or disability.

#### *Specialized Interventions*

Specialized interventions provided emerging evidence. Liu et al. reported improvements in pain, function, and muscle strength following combined IASTM and BFR [18], while Lee et al. found improvements in muscle function following low-intensity BFR combined with multi-joint exercise [28]. These findings suggest that BFR may have potential as an adjunct to strengthening, although the limited number of studies and differences in protocols restrict generalization. EMG biofeedback was also investigated as an adjunct to taping and demonstrated improvements in quadriceps strength and function [15]. These approaches should therefore be considered specialized adjuncts rather than substitutes for progressive exercise.

#### *Comparator-Specific Interpretation*

The comparator designs addressed different clinical questions and were therefore not considered equivalent. Trials comparing an intervention plus exercise versus exercise alone assessed add-on effects, such as the additional benefit of manual therapy reported by Abdo et al. [22]. Head-to-head comparisons, including static versus dynamic stretching and BMFO versus SMFO, evaluated relative effects between active interventions rather than superiority over no treatment [13,20,26]. Placebo-controlled comparisons, such as patellar taping versus placebo taping with the same strengthening program, assessed effects beyond the placebo intervention [21]. Comparisons with no active intervention, such as balance and perturbation training, address whether an intervention provides benefit compared with the absence of active treatment

[29]. Immediate post-treatment findings were also interpreted separately from outcomes measured after longer treatment or follow-up periods.

#### *Overall Clinical Implications*

The clinical implications of this review should be considered evidence-informed rather than prescriptive. The available evidence supports exercise-based rehabilitation as the core component of PFPS management, particularly for addressing strength, flexibility, neuromuscular control, and functional limitations. Manual therapy, soft-tissue techniques, taping, and foot orthoses may be used as adjunctive or context-specific interventions, while BFR, EMG biofeedback, perturbation training, and gait or foot-strike retraining may be considered targeted or specialized approaches when clinically relevant impairments are identified. However, the current evidence does not establish any single intervention as universally superior or as a definitive first-line treatment.

Treatment selection should consider patient characteristics, clinical impairments, functional limitations, biomechanical features, activity level, and treatment goals. Findings from athlete- or runner-specific studies should not automatically be generalized to the broader PFPS population, and the predominantly adult evidence should not be directly extrapolated to adolescents. Immediate changes in pain, balance, muscle activation, ground-reaction forces, or kinematics should also be distinguished from sustained improvements in pain and function and should be interpreted as short-term or hypothesis-generating evidence when long-term outcomes are unavailable.

#### *Limitations*

This review is limited by heterogeneity in participant characteristics, intervention protocols, comparators, treatment duration, follow-up, and outcome measures, which prevents definitive treatment ranking. Most studies had some concerns regarding risk of bias, and several interventions were evaluated in relatively small samples. Adherence, adverse events, withdrawals, co-interventions, and protocol deviations were inconsistently reported, limiting conclusions regarding treatment feasibility and safety.

The review did not include a formal quantitative meta-analysis or certainty-of-evidence assessment because of substantial clinical and methodological heterogeneity. Although PubMed/MEDLINE, PEDro, CINAHL, and Scopus provided complementary coverage, Embase and Web of Science were not searched, and grey literature, conference proceedings, dissertations, and unpublished trials were not systematically searched. Therefore, publication and retrieval bias cannot be excluded. Backward reference-list screening of included studies and relevant systematic reviews was used to identify potentially eligible reports not captured through database searching.

#### *Future Directions*

Future research should use adequately powered RCTs with standardized protocols, clinically meaningful outcomes, longer follow-up, and consistent reporting of adherence and adverse events. Direct comparisons should determine whether adjunctive interventions such as BFR, IASTM, taping, foot orthoses, EMG biofeedback, gait retraining, and perturbation training provide clinically meaningful benefits beyond progressive exercise alone. Further research should identify patient characteristics and biomechanical or functional impairments that predict response to specific interventions and should include adolescents and non-athletic populations to improve generalizability. Longer-term studies are also needed to determine whether observed biomechanical and neuromuscular changes translate into sustained improvements in pain and function.

## Conclusions

This systematic review of 18 RCTs found that contemporary physiotherapy and orthotic interventions were associated with improvements in selected outcomes, including pain, muscle strength, functional performance, balance, neuromuscular control, and lower-limb biomechanics in individuals with PFPS. Exercise-based rehabilitation, particularly strengthening and functional training, remains an important component of management, while manual therapy, stretching, proprioceptive training, taping, EMG biofeedback, instrument-assisted soft tissue mobilization, blood flow restriction training, biomechanical retraining, and foot orthoses may be useful as adjunctive or targeted interventions in appropriate clinical contexts. Overall, the findings support a progressive, individualized, and multimodal approach to PFPS management. However, substantial heterogeneity in interventions, comparators, outcome measures, treatment dosage, and follow-up, together with methodological concerns across several trials, limits definitive conclusions regarding comparative effectiveness. Larger, well-designed RCTs with standardized protocols and longer follow-up are needed to determine the sustained and comparative effects of these interventions.

## Additional Information

### Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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