Effect of Hip Abductors and Lateral Rotators Muscle Strengthening on Pain and Functional Outcome in Patients with Patellofemoral Pain: Systematic Review and Meta-Analysis

Abdulaziz Alammari

King Fahd Armed Forces Hospital

Nicola Spence

University of Salford School of Health and Society

Amitesh Narayan (✉ amitesh.narayan@manipal.edu)

Mangalore, Manipal Academy of Higher Education <https://orcid.org/0000-0001-7587-8414>

Shreekanth D Kamad

Kasturba Medical College Mangalore <https://orcid.org/0000-0002-7943-2644>

Zulfeequer Chundan Ottayil

Hamad Medical Corporation

Research

Keywords: Patellofemoral pain, patellofemoral pain syndrome, Anterior Knee Pain, Hip and Quadriceps and Hip muscles strengthening, Knee function, Systematic reviews, Randomised Controlled Trials.

Posted Date: August 10th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-778213/v1>

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Abstract

Background: This study systematically reviews and Meta-analyses the best-published evidence on the therapeutic value of strengthening hip abductors and lateral rotators muscles for the treatment of Patellofemoral Pain (PFP) with a presumptive hypothesis that strengthening hip muscles stabilises the patellofemoral joint, relieves pain and enhances knee functions.

Methodology: Electronic database searches of Medline, EMBASE, CINAHL, PEDro and PubMed Central between January 1994 and September 2019 using PICOS tool. The methodological quality of the selected studies was appraised individually using the 20-item McMaster Critical Review Form for Quantitative Studies. Supplemental quality appraisal of randomized controlled clinical trials performed using the Cochrane Collaboration's 'Risk of bias' quality criteria. Data on patient population demographics, interventions, duration of intervention and outcome measures were extracted, summarized in evidence tables and descriptive analysis made. Pooled effects size from appropriate RCTs was determined by meta-analysis under both fixed and random-effects models.

Results: All included fourteen studies demonstrated that hip muscles strengthening resulted in improved pain and knee function. All RCTs, except one, demonstrated that hip muscles strengthening is superior to quadriceps strengthening. Of the five RCTs accessing the surplus effect of hip-quad versus quadriceps strengthening, four suggested that hip-quad strengthening is superior over the standard quadriceps strengthening alone to improve PFP and knee function.

Conclusion and Implications: In patients with PFP, strengthening of hip abductors and lateral rotators have greater therapeutic significance than the conventional quadriceps exercises in improving knee pain and function both in the short- and long term. However, caution is required, because a standardized hip-quad protocol is yet to be developed, which warrants further studies.

Systematic review registration:

There was no protocol prepared and no amendments were present. This systematic review is registered under Open Science framework, with following registration digital object identifier 10.17605/OSF.IO/CWZ8V

Introduction

Patellofemoral pain (PFP) is characterised by anterior knee pain emanating from the patellofemoral joint involving patella and fibrous tissue on the medio-lateral retinaculum [1]. The aetiology is irregular patellar kinematics due to excessive pressure on the patellofemoral joint coupled with poor proximal neuromuscular control and hip muscle weakness [2–4]. The pain in PFP is because of inflammation coupled with damage to bony, cartilaginous or the connective tissues of the patellofemoral joint [1, 2, 5].

The PFP incidence rate is 25–40 % of all cases of anterior knee pain which is considerably high. Hence, therapeutic interventions are imperative to reduce permanent knee disabilities and improve quality of life [5–7]. The prevalence of PFP is higher in women and athletes than males (2:1) and is even higher (4:1) among athletes [6].

The works of literature on musculoskeletal injuries indicate a positive correlation between hip muscles weakness and PFP [8–10]. In a case report on PFP, authors noted that excessive hip adduction coupled with the weakness of the hip extensors and abductors are predominantly musculoskeletal concerns [10]. The current physiotherapy evidence strongly supports quadriceps muscle strengthening as an effective strategy to improve overall knee function in patients with PFP [11–13]. The proximal hip muscles exercises reported to be effective in relieving patellofemoral pain and improving knee function when compared to knee exercises alone [14]. Therefore, strengthening these muscles underlies the objective treatment of PFP. While quadriceps strengthening is already the standard physiotherapeutic target for PFP, it is plausible that strengthening of hip muscles will serve greater benefits, because of its effect on greater control over the knee biomechanics [5, 15].

Relationship between Hip Muscles (abductors and external rotators) Strength and PFP

Muscles of the hip (hip abductors and external rotators) are essential for knee and pelvic stabilization during ambulation [5]. The hip abductors and external rotators act synergistically to eccentrically control the hip adduction and internal rotation movements, respectively [15–17]. The diminished strength of hip abductors and external rotators muscles may result in poor neuromuscular control during activities that necessitate loading on the patellofemoral joint [5, 8, 18]. The weak hip abductors may cause excessive femoral adduction, thereby, augmenting lateral forces (Knee Valgum) acting on the patella [19]; while, weak hip external rotators results in unrestricted internal rotation of the femur, that augments contact pressure between the lateral facet of the patella and lateral femoral condyle [19]. Hence, weak hip muscles (mainly hip abductors and external rotators) is an important aetiological factor for PFP [5, 15, 20, 21].

Many studies compared the effectiveness of hip muscles strength in patients with PFP to matched healthy controls [16, 21–23]. Ireland et al. reported eccentric muscle strength reduction of 26% in hip abductors and 36% in hip external rotators among females with PFP while Souza & Powers, found a reduction of 14% in hip abductors and 17% in hip external rotators eccentric muscle strength compared to healthy matched

controls [16, 21]. Nevertheless, Piva et al. found no significant muscle strength differences for hip abductors and external rotators in patients with PFP compared to healthy age/gender-matched controls; however, Baldon et al. reported significantly reduced strength for eccentric hip abductors, but not for hip external rotators among females with PFP to healthy matched controls [22, 23].

The weak hip lateral rotators cause unrestricted internal rotation of the femur about the tibia, enhancing misalignment at the knee joint that in turn leads to a biomechanical imbalance between the hip extensors and lateral rotators, that overloads the retinaculum and subchondral bone and subsequently potentiate patellofemoral pain and knee dysfunction [21]. Nevertheless, Earl et al. opined that strong hip muscles (abductors and external rotators) reverses these effects over the knee joint [3].

Ireland et al. and Souza & Powers noted more weakness in hip external rotators compared to hip abductors in patients with PFP [16] [21]. Ferber et al. found that in patients with PPS, the three weeks of isolated hip abductors strengthening not only reduces patellofemoral pain but also increases gait-related knee-joint stability [9]. Two recent randomised controlled trials found that isolated strengthening of hip abductors and external rotators effectively relieves pain and improves knee function in females [4, 17]. The available pieces of evidence for PFP considered exercises to strengthen the hip muscles that reduces pain and enhances long-term knee function [3, 4, 6, 17, 24].

Outcome Measures of Pain, Knee Function and Health Status in PFP:

The available studies used self-reported Kujala Anterior Knee Pain Scale (AKPS), Visual Analogue Pain (VAS) scale, 11-point Numerical Pain Rating Scale (NPRS) and Pain Severity Scale (PSS) as an outcome measure to document patellofemoral pain in patients with PFP receiving therapeutic interventions [14, 25, 26].

The knee functions for patellofemoral pain were assessed using the Lower Extremity Functional Scale (LEFS), Tegner Activity Scale (TAS), Lysholm Knee Scoring Scale (LKSS)/ Tegner Lysholm Knee Scoring Scale (TLKSS), Knee Outcome Survey-Activities of Daily Living Scale (KOS-ADL) and Functional Index Questionnaire (FIQ) [26–30].

Though, the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) is tailored to examine the functional status of osteoarthritis, is also been used to measure health status for patients with patellofemoral pain [because patients with osteoarthritis often present with anterior knee pain which is similar to patellofemoral pain] [25].

Since, systematic reviews evaluating the effect of hip abductors and lateral rotators strengthening for patellofemoral pain, knee function and quality of life in patients with PFP are extremely limited, even though, evidence indicating the presence of weak hip abductors and external rotators. Primarily this study systematically reviews and Meta-analyses the best-published evidence on the therapeutic value of strengthening hip abductors and lateral rotators muscles for the treatment of PFP. This is being guided by the presumptive hypothesis that strengthening hip muscles stabilises the patellofemoral joint, relieves pain and enhances knee functions.

Methodology

Justification of the Systematic Review Approach

Systematic reviews and meta-analyses are important methodologies for the qualitative and quantitative synthesis of published evidence. Shreds of evidence presented in systematic reviews are key for continuous quality and safety improvements in evidence-based clinical practice and therefore, useful for both clinicians and healthcare policymakers. The present review study used Centre for Reviews and Dissemination (CRD) guidance for undertaking reviews in health interventions to assess the value of hip muscles strengthening as therapeutic interventions in patellofemoral pain and knee function in patients with PFP [31]. Additionally, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, recommended in CRD's guidance is used in literature searches to minimise biases in article selection and reporting [32]. The review has been registered with Open Science framework with reference doi: 10.17605/OSF.IO/CWZ8V

Electronic bibliographic database searches

The controlled clinical trials (randomised and non-randomised), controlled comparative studies and cohort studies ((prospective and retrospective) published in the last 25 years (January 1994 to September 2019) in English language journals were performed across five electronic databases [Medical Literature Analysis and Retrieval System Online (Medline); Excerpta Medica Database (EMBASE); Clinical Index of Nursing and Allied Health Literature (CINAHL); Physiotherapy Evidence Database (PEDro) and The Cochrane Central Register of Controlled Trials (CENTRAL)]. Appropriate combinations of Medical Subject Headings (MeSH) or CINAHL headings with keywords (Table 1) using Boolean Operators (AND, OR & NOT) along with PICOS (target population, intervention, comparator, outcomes and study design) were used [33].

Additional electronic searches are done in the Meta register of Controlled Trials (mRCT) via the Current Controlled Trials (CCT) database to locate ongoing RCTs with potentially relevant data useful for the present systematic review. The potentially relevant clinical controlled trials and cohort studies (otherwise not indexed in any of the five electronic bibliographic databases and mRCT), electronic searches were supplemented by

searching unpublished papers from the OpenGrey (formerly SIGLE) database. The literature searches were additionally supplemented with manual bibliographic searches of relevant systematic reviews, editorials and thesis reports published by the digital libraries of the University of Manchester, University of Central Lancashire and Australian Digital Thesis programmes including ProQuest. Authors of potentially relevant unpublished reports were contacted by e-mails seeking clarification of their respective studies with the possibility of inclusion in the present review.

Study Selection

The study selection performed by the PRISMA flow chart where returned hits for each electronic bibliographic database were screened initially based on title and abstracts. The number of potentially relevant articles were noted and citations imported into Endnote citation manager (EndNote X7), and full-text articles retrieved for further eligibility screening. Studies were included based on the following criteria:

Inclusion criteria

1. Studies that enrolled adolescents (≥ 14 to ≤ 19 years) and/or adults (≥ 50 years);
2. Studies involving patients with the confirmed clinical diagnosis of patellofemoral pain presented with anterior or retro patellar knee pain during physical activities i.e. running, climbing staircase, squatting, hopping, and kneeling or prolonged sitting;
3. Studies involving patients diagnosed with patellofemoral pain without underlying knee pathologies (e.g. Osteoarthritis), previous knee trauma or surgery;
4. Only controlled clinical trials (RCTs, Non-RCTs, and comparative studies) and cohort studies assessing the effect of hip abductors and/or external rotators strengthening on pain and functional outcomes of patients with a confirmed diagnosis of patellofemoral pain;
5. Studies published as books, chapters or conference abstracts or interim results in the mRCT database provided that authors were contacted successfully;
6. Studies comparing strengthening of hip abductors and/or external rotators muscles with standard quadriceps strengthening or no exercises;
7. Studies where the intervention group received hip muscles strengthening exercises coupled with quadriceps strengthening provided that the comparator group received only the quadriceps strengthening protocol;
8. Studies measuring pain by VAS, AKPS, 11-point NPRS, PSS, and functional outcomes examined on TAS, LKSS, FIQ, TLKSS LEFS, PFJES, or WOMAC instruments;
9. Studies published in English only were included for the review.

Exclusion criteria

1. Studies that were not quantitative such as reviews, editorials, commentaries, which merely reviewed the physiotherapeutic benefits of hip muscles strengthening to patients with patellofemoral pain;
2. Studies published more than 20 years ago;
3. Studies that recruited PFP patients with other underlying knee pathologies such as knee osteoarthritis, knee cartilaginous injuries, meniscal tears or knee surgery;
4. Studies that included the non-exercise co-interventions such as electro-muscular stimulation (electrotherapy), patella taping, and orthotics;
5. Studies reported neither patient pain nor functions.

Critical Appraisal of Methodological Quality

The McMaster Critical Review Form for Quantitative Studies applied to examine the methodological quality of all selected studies for study's objectives, literature survey, study design, sample population, intervention, outcome measures, results, significance, limitations, and conclusions (Table 2) [14]. Knowing that biases are the main threats to the internal and external validity of RCTs, quality appraisal of RCTs performed using The Cochrane Collaboration's 'Risk of bias' tool tailored specifically for RCTs [34]. The risk of patient selection bias was examined for the selected RCTs for the sufficiency of random sequence generation and concealment allocation to interventional and control groups. This helped to determine the comparability of the study groups at baseline. The risk of performance bias was evaluated based on measures (such as single blinding or double-blinding) employed to ensure study participants and personnel are blinded to interventions and outcomes. The risk of detection bias was assessed to know if the assessors were adequately blinded to patient group allocation. The risk of attrition bias and the risk of incorporation bias examined based on the rate and pattern of the dropout of participants, handling of incomplete outcome data and the indications of intention-to-treat (ITT) analysis. Finally, the risk of reporting bias evaluated based on the possibility of selective outcome reporting. The reproducibility of exercise therapies prescribed, confounding/modifying effects of co-interventions and the levels of supervision and patient compliance to the prescribed physiotherapy during the trial were also evaluated across the RCTs studies.

Data Extraction and Qualitative Synthesis

Data on effect measures were extracted for baseline patellofemoral pain levels, hip exercise interventions, including the comparator treatment, quantitative assessment of patient outcomes for patellofemoral pain and functions, follow-up duration and post-intervention practices during the follow-up periods. Statistical results (mean differences from baseline and effect measures *P* value at 95% confidence interval) were taken from the evidence tables for interventional studies (separately for controlled clinical trials and cohort studies).

Quantitative Synthesis (Meta-Analysis)

Using MedCalc software (Version 14.10.2, MedCalc Software Ltd), data from RCTs that provided the mean difference of pain or knee function between the intervention and the comparator groups were pooled by random or fixed-effect models to obtain standardised mean differences. Separate forest plots were generated for pain and knee function outcome.

Results

The primary electronic searches in the five bibliographic databases using the PICOS search strategy returned 114 potentially relevant citations. Through careful screening for duplicates based on titles and authors, 50 citations were excluded. The 43 articles were excluded after careful screening of titles and abstracts from the remaining 64 articles because they were not irrelevant. The full texts of the remaining 21 articles were evaluated rigorously for eligibility based on the inclusion and exclusion criteria, and through this process, 10 studies were excluded because of the following reasons;

1. Six articles excluded because they involved patients with knee osteoarthritis or mixed participants with PFP and osteoarthritis,
2. Two studies excluded because they focused on hip/quadiceps muscle strengths as the only outcome measure after interventions without assessing pain or functional outcomes,
3. One study appeared relevant, but lacked the description of exercise interventions administered,
4. Lastly, one study contained duplicate experimental data from another included original study.

Three potentially relevant studies were identified through manual bibliographic hand searches of three recent systematic reviews [14,35,36]. The complete process yielded 14 studies. Among these, 10 were controlled clinical trials (CCTs), and 3 were cohort studies while 1 was a case series [3,4,6,9,17,24,37–44]. The 3 cohort studies met the inclusion criteria for qualitative synthesis. Nine controlled clinical trials were true randomised controlled trials (RCTs) presenting data suitable for quantitative synthesis (meta-analysis) [4,6,17,24,37–39,41,42]. The literature search strategy and article selection process are summarised in the PRISMA flow chart (Fig. 1) [32].

Controlled Clinical Trials

A total of 383 participants from the 10 CCTs received either hip-strengthening exercises (N=74) or quadriceps strengthening exercises (N=157) or hip/quadiceps strengthening exercises (N=108) or no exercise (N=44) (Table 2). All CCTs involved true randomization of participants except one, where participants were allocated to their respective groups alternately in a consecutive manner [40].

Intervention Protocol:

In all CCTs, the hip muscles strengthening protocol focused on hip abductors and lateral rotators. The hip exercise protocol included hip abduction against an elastic band while standing, or with weights in side-lying position coupled with hip lateral rotation against an elastic band while seated and hip extension; quadriceps strengthening involved closed kinetic chain exercise or seated knee extension, leg press, squatting and stretching of hamstrings and quadriceps; and, hip-quadriceps strengthening involved combination of the hip-quadriceps protocol. The duration of intervention ranged from 3- 8 weeks, while the frequency of therapy sessions ranged from 2-4 per week (Table 3).

Outcome measures

All CCTs examined both pain and functional outcomes except one, which assessed only pain [41]. The pain was commonly evaluated using 10-cm VAS by all CCTs except two, which used the 11-point NPRS [4,24]. The pain was evaluated during ascending and descending stairs [4,24,41], squatting, usual pain [41], and worst knee pain in the previous week [6,17,39–42]. Functional outcomes were assessed using LEFS [4,6,24,38], AKPS [4,6,24,39], PFJES [37], TLKSS [42] and WOMAC [17,40].

Follow-up duration

Post-intervention measures were immediately carried out at the end of the intervention period in all studies. However, the post- interventional follow-up period ranged from one to twelve months (Table 4).

Critical appraisal

Methodological quality assessment of the 10 CCTs based on the Cochrane Collaboration's 'Risk of bias' tool tailored for RCTs is detailed in Table 5 & 6 below [34].

I. Cohort and Case Series Studies

The three cohort studies had 88 participants [PFP (n=64); healthy controls (n=24)]. The one case series involved 19 participants with PFP.

Intervention Protocol:

In one cohort study, the experimental group given hip muscles exercise protocol (strengthening of hip abductors and external rotators), and the control group received knee exercises. The other two cohort studies subjects received quadriceps- strengthening [43,44]. The duration of intervention ranged between three to six weeks. The case series participants completed an eight-week exercise programme focusing on hip muscles strengthening and improving dynamic misalignment (Table 7).

II. Meta-analysis (pooled effect size)

The meta-analysis was done to determine the additional effect of hip muscles strengthening as adjunctive therapy to the standard quadriceps strengthening for PFP and knee function.

A. The comparative effect size of Hip versus Quadriceps strengthening on pain and function

Two RCTs [6,38] and one comparative control trial [40] provided data that compared the effect of the isolated strengthening of hip muscles (hip abductors and lateral rotators) versus the standard quadriceps strengthening on PFP and knee function. A total of 100 participants were randomly assigned to receive either hip (n=50) or quadriceps (n=50) strengthening protocols. The standardised mean difference (SMD) of PFP and functional outcomes after intervention with 95% CI under both fixed and random effects models favoured hip muscles strengthening over quadriceps strengthening ($p<0.001$) (Fig. 2 and 3).

B. Surplus effect of hip-quad versus quadriceps strengthening on pain and function

Five RCTs contributed data assessing the surplus effect of hip muscles strengthening coupled with quadriceps strengthening compared to the standard quadriceps strengthening alone on PFP and knee function [4,24,39,41,42]. For both the group (hip-quad and quadriceps alone), 16 data sets were collected from a total of 98 participants. The pooled effects of results are presented in forest plots Fig. 4 and 5 as cumulative SMD with 95% CI, under both fixed and random-effects models.

Discussion

Two recent systematic reviews have demonstrated that proximal exercises targeting quadriceps and hip muscles strengthening were effective in relieving pain and improving knee function in patients with PFP, both the short- and long-term [14,36]. However, this systematic review was important to delineate the effect of the isolated strengthening of hip abductors and lateral rotators on pain and knee function in patients with PFP compared to non-exercise interventions and to identify if hip muscles strengthening is superior over the quadriceps strengthening alone among them.

A. Quality of the Summarised Evidence

The methodological quality of the fourteen studies except five i.e. [6,9,37,43,44] included in the present review is excellent because it fulfilled 14 of the 16-item McMaster critical review criteria. The common methodological issue observed in the majority of the selected studies was lack of sample size justification (sample size not determined or not achieved) [6,17,37,39,40,43]. All studies with sample power inadequacy issue, achieved results with statistical significance, suggesting that the measured pain and functional outcomes reflect the comparative effect of the interventions. However, subject contamination in Dolak et al. was evident because hip and quadriceps groups were combined as one to receive functional strengthening exercises (as co-interventions for the last four weeks of the intervention) [6]. Such subject contamination might have caused patient bias for their pain and functional outcomes, especially if they know the intervention of their cohorts in the opposite arm of the study [45].

This risk of bias is a critical methodological issue in RCTs and warranted supplementary quality appraisal of all RCTs on the Cochrane Collaboration's 'Risk of bias tool' [34] to highlight methodological flaws (indicative of 'Risk of bias' threatening interval consistency) (Table 6). All RCTs except two recruited participants with a confirmed diagnosis of PFP [17,40]. However, these studies were included because they enrolled patients presented with anterior knee pain based on symptoms matching the inclusion criteria of the remaining RCTs, which recruited patients with a confirmed diagnosis of PFP. Here, 383 participants from all RCTs presented with anterior knee pain associated with prolonged sitting, climbing stairs and descending stairs in the absence of signs/symptoms of meniscal or other intra-articular pathological conditions, or history of

other knee pathologies, surgeries and injuries. These are classical symptoms for the diagnosis of PFP [14,36]. However, these symptoms may be indicative of knee osteoarthritis, but it may not be so likely because patients enrolled in RCTs were not older than 50 years of age, and therefore not likely to present with ageing-associated PFP [46].

Four studies included the mixed population of both adults and adolescents aged 17 to 50 years [6,38,39,41]. Since adolescents are physically active, therefore, at risk of PFP, hence, the inclusion of this age group [46]. To minimise the possibility of recruiting participants with underlying knee pathologies i.e. knee osteoarthritis, no studies recruited patients with PFP who were older than 50 years of age [46]. The four studies examined only female participants, therefore, the outcome may only be generalised for the female patients with PFP, but not for the males [4,6,24,38]. The three studies [39,41,42], included both males and female participants (proportion of females was higher than males), indicative of females being the greater risk of PFP than males [6]. This may be attributed to the lower hip muscle mass in females compared to males [47], therefore, females exhibiting lower hip muscle strength than males [47,48].

The symptom duration is a direct measure of severity of PFP that has a significant influence on therapeutic outcome [49]. Therefore, patients with early diagnosis of PFP likely to respond well to therapy compared to those with late diagnosis [20]. Thus, symptom duration is a key confounding variable that needs to be adjusted via the subject's stratification. In this systematic review, the mean duration of symptoms of participants with PFP in eight studies ranged from 17 to 21 months. However, six studies [17,37–41] did not report the mean duration (months) of PFP symptoms. None of the studies performed the subject's stratification for the PFP severity and symptom duration. This might have positively skewed pain and functional outcomes in patients with a shorter mean duration of symptoms [20]. Additionally, the subject's characteristics were barely explained in three studies [38,40,41] and also not detailed in one study [37]. These findings undermine the quality of the summarised shreds of evidence.

Supervised therapeutic exercises enhance participant's compliance because unsupervised participants may refrain from pain-provoking exercises [20,50]. Two previous RCTs had reported that supervised exercises for PFP result in less pain and better knee function at short- and long-term follow-up compared to usual care [20,50]. In the present systematic review, all studies involved exercises administered in physiotherapy facility/ rehabilitation setting under supervision by qualified physiotherapists, except two [6,41], where two-thirds of exercise sessions were self-administered in patients homes (unsupervised), while one-third had at rehabilitation facility under supervision. It had an important bearing on patient compliance to intervention and the outcome. Even then, results were significant in these two studies suggesting that partial supervision too can yield clinically significant results.

B. Isolated Hip Musculature Strengthening

All fourteen studies demonstrated that isolated strengthening exercises of hip abductors & lateral rotators for two to four times per week up to three to eight weeks duration is effective in relieving pain and improving knee function compared to quadriceps strengthening and non-exercise interventions. Kooiker et al. reported variations in quadriceps, hip and hip-quadriceps strengthening protocols in selected studies, and opined for the unavailability of standardized protocols for PFP [36]. The common hip exercise protocol included hip abduction against an elastic band while standing, and with weights in a side-lying position coupled with hip lateral rotation against an elastic band while seated and hip extension (3 sets of 10 repetitions). Conversely, quadriceps strengthening in all studies generally involved weight-bearing and non-weight-bearing exercises such as closed kinetic chain exercises, seated knee extension, leg press, squatting and stretching of hamstrings and quadriceps (3 sets of 10 repetitions).

The hip protocol generally resulted in improved pain and knee function after three to eight weeks of training, with long-term effects observed as late as twelve months post-intervention [24]. Four studies evaluated comparative therapeutic value of quadriceps versus hip muscles strengthening in treating PFP [6,37,38,40]. One study by Khayambashi et al. reported superiority of hip muscles strengthening strategy over the quadriceps strengthening for both pain and functional improvement in PFP [40]. The remaining three studies opined that isolated hip and quadriceps strengthening strategy have comparable therapeutic value for the PFP [6,37,38]. However, a meta-analysis of the effect measures (pain and function) as measured on VAS and LEFS or WOMAC revealed that hip strengthening significantly favours over the standard quadriceps strengthening ($p < 0.001$) in PFP treatment [6,38,40].

C. Surplus Therapeutic Effect of Hip Muscles Strengthening

Though the proximal strengthening exercises involving quadriceps and hip muscles are commonly effective in treating PFP, Kooiker et al., Peters & Tyson opined that a combination of hip-quadriceps strategy could add the therapeutic outcome for the patients with PFP [6,14,36–38]. The present systematic review included five RCTs to examine the surplus therapeutic outcome of hip-quadriceps strengthening exercises over the standard quadriceps [4,24,39,41,42]. All studies except one supported that hip-quadriceps strategy was superior to the standard quadriceps [42].

The findings of these five RCTs have both internal and external validity and are, therefore, acceptable. Furthermore, meta-analysed data of these five studies strongly indicated that quadriceps coupled with hip muscles strengthening has significant surplus therapeutic benefits over the

conventional quadriceps or the hip exercises in the treatment of PFP ($p < 0.001$). Therefore, a hip-quadriceps strategy should be adopted in clinical practices for pain relief and optimal functional improvements in patients with PFP.

Limitations

The summarised pieces of evidence supported by meta-analyses indicate that strengthening of hip muscles is effective in treating PFP for pain and knee function of physically active male/female adolescents and adults. However, a few but important limitations must be noted;

1. This systematic review and meta-analysis initially were intended to review a minimum of 20 studies to examine the therapeutic outcome of hip muscles strengthening versus quadriceps alone on pain and knee functions for patients with PFP. The expanded literature search yielded only 14 studies that are adequate for systematic review limits the strength and generalisability of the summarised findings over a wider population of patients with PFP.
2. Avraham et al. study (included in this review) used a non-exercise (electrotherapy) as a co-intervention that might have uni-directionally augmented the therapeutic effects [37].
3. Though the proportion of females to males is higher in all studies (included in this review), but this may not be considered as a limitation to generalisability for a wider group of patients with PFP, because it truly reflects the characteristics of patients with PFP that would be encountered in day-to-day clinical practice.

Implications for routine physiotherapy practice

The evidence from the present review has important implications in routine clinical practice for the patients with PFP:

1. Strong shreds of evidence favour hip muscles strengthening exercises for two to four times a week, up to three to four weeks, to have effective therapeutic outcome compared to standard quadriceps strengthening exercises alone in patients with PFP. This implies that therapists should consider hip muscles strengthening as standard therapeutic measures while treating patients with PFP.
2. Meta-analysis of the effect measures (both pain and function) has strongly supported that hip muscles coupled with quadriceps (hip-quad) strengthening has superior therapeutic effects compared to the individual isolated hip or quadriceps strengthening exercises. This evidence strongly implies that therapists should consider a combination of hip and quadriceps strengthening exercises for the treatment of patients with PFP. However, this may imply longer therapy sessions plus more sessions per week that may influence patient's compliance to intervention, especially if prescribed as self-efficacy [51].
3. In the present review, only one study [24] out of fourteen had followed patients up to twelve months, which was a good attempt to determine the long-term therapeutic effect of hip versus quadriceps strengthening exercises on PFP and knee function. This is indicative of evidence to be generalised only for the short-term, instead of long-term pain and functional outcomes.

Future Research

Must consider stratification of patients/results based on the symptom duration before the intervention, to eliminate the effect of time-delay modification on pain and functional outcomes following hip muscles strengthening in patients with PFP.

Conclusion

The results of this systematic review and meta-analysis indicate that isolated strengthening of hip abductors and lateral rotators has therapeutic benefits compare to quadriceps strengthening alone for the treatment of PFP. It is also clear that the hip-quadriceps strategy gives a greater therapeutic outcome than isolated quadriceps or hip muscles strengthening. Therefore, we recommend developing a hip-quadriceps exercise strategy for the treatment of PFP to encourage improved compliance, even in unsupervised patients.

Abbreviations

PFP: Patellofemoral pain; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; CRD: Centre for Reviews and Dissemination

Declarations

Funding: No funds, grants, or other support was received for conducting this study

Conflicts of interest/Competing interests: The authors have no financial or non-financial conflicts of interest to declare that are relevant to the content of this article

Code availability: Not applicable

Authors' contributions:

AAA: Conception and design; Literature search; Data acquisition; Data entry and analysis; Manuscript preparation.

NS: Conception and design; Defining intellectual content; Data interpretation; Manuscript editing and review

AN: Conception and design; Defining intellectual content; Data interpretation; Manuscript editing and review

SKK: Manuscript editing, review, submission

ZCO: Data interpretation and review

Ethics approval: Ethical approval was waived as human subjects were not directly contacted or included in the study.

Consent to participate: Not Applicable

Consent for publication: Authors have no objections regarding publications of study data.

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Tables

Table 1: Medical Subject Headings (MeSH) terms and keywords for PICOS search strategy

	Common MeSH terms	Text words (keywords)
Population	Humans, adult, female, male adolescents and young adults	"Patellofemoral pain", "Anterior knee pain", "Chondromalacia patella"
Intervention	Exercise Therapy, Exercise Therapy/methods, Physical Therapy Modalities, Patellofemoral Pain Syndrome/rehabilitation, Hip physiology, Knee Joint physiopathology, Combined Modality Therapy	Exercise-based interventions targeting hip muscles strengthening "hip exercises" or "hip-strengthening exercises."
Comparator	Quadriceps Muscle physiology/ physiopathology,	Exercise-based interventions targeting knee muscles strengthening or stretching (quadriceps protocol): "quadriceps strengthening exercise", "knee strengthening exercise", "Knee stretching exercises" and "knee stabilizing exercises" OR no treatment
Outcomes	Treatment Outcome, Pain Measurement, Recovery of Function	<p>Anterior knee pain: "pain measurement", "The Kujala Anterior Knee Pain Scale"(AKPS), "The Visual Analogue Pain Scale" (VAS), 11-Point Numerical Pain Rating Scale"(NPRS), "self-reported pain", "Pain Severity Scale"(PSS).</p> <p>Function: "knee function", "functional outcome questionnaire for the knee pain," "Lower Extremity Functional Scale" (LEFS), "Tegner Activity Scale"(TAS), "Lysholm Knee Scoring Scale" (LKSS), "Tegner Lysholm Knee Scoring Scale" (TLKSS), "Knee Outcome Survey-Activities of Daily Living Scale" and "Functional Index Questionnaire" (FIQ), "Patello-femoral joint evaluation scale" (PFJES)</p> <p>Health status: "Western Ontario and McMaster Universities Osteoarthritis Index"(WOMAC)</p>
Study types (design)	Publication types: controlled clinical trial, randomised controlled trial, non-randomised controlled trial, controlled comparative study, comparative study, cohort studies, follow-up studies, observational studies (prospective study, retrospective study, case series), systematic reviews	

Table 2: Methodological quality of selected studies rated on McMaster critical review form

Author (s)	Study design	Level of evidence	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Score /16
Avraham et al., 2007	RCT	Level 2b	✓	✓	✓	✓	×	×	×	×	✓	✓	×	✓	✓	✓	✓	✓	10/16
Baldon et al., 2014	RCT	level 1b	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	15/16
Dolak et al., 2011	RCT	level 2b	✓	✓	✓	✓	×	✓	✓	×	✓	×	×	✓	✓	✓	✓	✓	12/16
Fukuda et al., 2010	RCT	level 1b	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16/16
Fukuda et al., 2012	RCT	level 1b	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16/16
Ismail et al., 2013	RCT	Level 2b	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	14/16
Khayambashi et al. 2014	CCT	Level 2b	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	14/16
Khayambashi et al. 2012	RCT	Level 2b	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	14/16
Nakagawa et al., 2008	RCT-p	Level 2b	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	15/16
Song et al., 2009	RCT	level 1b	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16/16
Tyler et al., 2006	CS	Level 2b	✓	✓	✓	✓	✓	✓	✓	✓	✓	n/a	✓	✓	✓	✓	×	✓	14/16
Boling et al., 2006	CS	Level 2b	✓	✓	✓	✓	×	✓	✓	✓	✓	n/a	✓	✓	✓	✓	✓	✓	14/15
Earl & Hoch, 2011.	CSr	Level 4	✓	✓	✓	✓	✓	✓	✓	✓	✓	n/a	✓	✓	✓	✓	✓	✓	15/15
Ferber et al., 2011	CS	Level 4	✓	✓	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	×	✓	13/16
Total			14	14	14	14	8	11	12	11	14	6	12	14	14	14	12	14	

RCT= randomised controlled trial, CCT= comparative control trial RCT-p = randomised controlled pilot study, CS= cohort study, CSr= case series:

Key: ü= yes (criterion fulfilled), × = No (criterion not fulfilled/not clear), n/a= Not applicable

1. Is the study question and aims clear?; 2. Is the background literature review adequate leading to the research questions and objectives?; 3. Is the selected study design and study setting appropriate?; 4. Is the study sample characteristic suitable?; 5. Is the sample size adequate and justified?; 6. Is the study ethical?; 7. Is the reliability of outcome measures reported?; 8. Is the validity of outcome measures reported?; 9. Is intervention descriptions clear and adequate?; 10. Was contamination of sample populations avoided?; 11. Is co-interventions are avoided?; 12. Are results reported in terms of statistical significance?; 13. Were appropriate statistical analyses were performed?; 14. Were clinical significance of the findings are reported?; 15. Were participants' drop-outs and withdrawals the reported?; 16. Are the author's conclusions appropriate?

Table 3: Participants allocation in intervention and non-intervention groups with the duration of intervention and frequency of therapy in weeks

Study	Duration of Intervention	Frequency of Therapy	Hip (N)	Quad (n)	Hip-Quad (n)	No Exercise (n)	Total (N)
Dolak et al. 2011	4 Wks	3 per Wk	17	16		-	33
Baldon et al. 2014	8 Wks	3 per Wk	15	16			31
Khayambashi et al. 2014	8 Wks	3 per Wk	18	18			36
Nakagawa et al. 2008	6 Wks	4 per Wk	7	7			14
Fukuda et al. 2010	4 Wks	3 per Wk	20	21			41
Fukuda et al. 2012	4 Wks	3 per Wk	24	25			49
Ismail et al. 2013	6 Wks	3 per Wk	16	16			32
Avraham et al. 2007	3 Wks	2 per Wk	10	10	10		30
Song et al. 2009	8 Wks	3 per Wk	-	30	29	30	89
Khayambashi et al. 2012	8 Wks	3 per Wk	14	-		14	28
Total (N)			74	157	108	44	383

Table 4: Follow-up duration and interval post-intervention pain/functional outcome measures

Authors	Immediately	1-mo*	3-mo	6-mo	12-mo
Avraham et al., 2007	✓	×	×	×	×
Baldon et al., 2014	✓	✓	×	×	×
Dolak et al., 2011	✓	×	×	×	×
Fukuda et al., 2010	✓	×	✓	✓	✓
Fukuda et al., 2012	✓	×	✓	✓	✓
Ismail et al., 2013	✓	×	×	×	×
Khayambashi et al. 2014	✓	×	×	✓	×
Khayambashi et al. 2012	✓	×	×	✓	×
Nakagawa et al., 2008	✓	×	×	×	×
Song et al., 2009	✓	×	×	×	×

*Month

Table 5: Evidence table for controlled clinical trials

Authors Study design	Patient sample size & characteristics	Description of interventions and setting	Comparator exercise and setting	Follow-up duration & outcome measures	Effect size & summary of key findings
Avraham et al. (2007) Single-blinded randomised clinical trial (A pilot trial)	N=30; Patients with a confirmed diagnosis of PFP Ratio of male: female not indicated Mean age: 35 yrs.	Hip group (N=10) Participants underwent an exercise program targeting strengthening of hip external rotators 3-week exercise protocol with supervision involved: 90° knee flexion/extension exercise, hamstring/iliotibial band stretches coupled with electrotherapy 2 times per week. Hip/quadriceps group (N=10) Participants received exercise targeting hip and quadriceps musculature. This was coupled with electrotherapy 2 times per week Setting: Rehabilitation facility.	Quadriceps group (N=10) Participants received quadriceps strengthening exercise involving: straight leg raise (SLR), single-leg squats coupled with electrotherapy 2 times per week Setting: rehabilitation facility.	Pain assessed by numeric visual analogue scale (VAS) Function assessed by Patello-Femoral Joint Evaluation Scale (PFJES) Measured at baseline and 3 wks. post-intervention	All groups exhibited significant improvements in VAS and PFJES scores ($p<0.0001$). Between-group differences in pain and function were not statistically significant ($p>0.05$).
Nakagawa et al. (2008) Prospective, single-blinded randomised controlled design (A pilot trial)	N=14; (10 females and 4 males) Patients with a confirmed diagnosis of PFP Age range: 17–40 yrs. [mean $\pm$ SD 23.6 $\pm$ 5.9 yrs.] Hip/quadriceps group (n=7)- Group characteristics not defined Quadriceps group (n=7)- Group characteristics not defined	Hip/quadriceps group (N=7) Hip/quadriceps protocol involved strengthening of hip abductors, lateral rotators and transverse abdominis coupled with quadriceps protocol. Exercise performed once a week under supervisions and 4-times a week at home under no supervision for 6 weeks. Setting: rehabilitation facility with a home programme	Quadriceps group (N=7) Quadriceps protocol involved patellar mobilization, stretching of the quadriceps, gastrocnemius, hamstrings and iliotibial band coupled with open and closed kinetic chain exercises for quadriceps strengthening. Exercise performed once a week under supervisions and 4-times a week at home under no supervision for 6 weeks. Setting: rehabilitation facility with a home programme	Perceived pain symptoms during functional activities assessed by VAS Measured at baseline and 6 wks. post-intervention	The hip/quadriceps group exhibited significant improvement in pain symptoms ($p=0.02-0.04$) except during prolonged sitting: Mean difference (at 6 weeks-baseline) in usual pain -3.6 ± 2.6 ($p=0.03^*$), worst pain -2.6 ± 2.5 ($p=0.03^*$), Stair climbing -3.0 ± 3.2 ($p=0.04^*$), Descending stair -4.1 ± 2.9 ($p=0.03^*$), and Squatting -5.4 ± 3.0 ($p=0.02^*$) significant, but not prolonged sitting -1.9 ± 2.9 ($p=0.14$). No significant pain improvement in the quadriceps group ($P>0.05$).
Song et al. (2009) Randomised controlled trial	N=89; (69 females and 20 males) with a confirmed diagnosis of PFP	LPHA group (N=29) 50-N isometric hip adduction/abduction for strengthening hip abductors coupled with leg-press exercise for quadriceps strengthening.	LP group (N=30) Leg-press exercise performed unilaterally from 45° of knee flexion to full extension assisted by an EN-Dynamic Track machine.	Worst pain in the previous week rated on a 10-cm visual analogue scale (VAS-W). Knee function evaluated by Tegner Lysholm Knee Scoring Scale	The LPHA group: Exhibited significant improvements in VAS-W ratings ($p<0.005$) with mean difference of 2.18 (3.17-1.19; 95% CI) and Tegner Lysholm ($p<0.005$) with a mean score difference of 10.93 (7.27 to 14.59; 95% CI)

	<p>Mean age: 41 yrs.</p> <p>Hip adduction/leg-press Exercise (LPHA) group: (N=29) - (8 men; 21 women); Mean $\pm$SD age: 38.6 $\pm$10.8 yrs.</p> <p>Mean $\pm$SD duration of symptoms: 41.8 $\pm$36.1 months</p> <p>Leg-press Exercise only (LP) group (N=30) - (8 men; 22 women); Mean $\pm$SD age: 40.2 $\pm$9.9 yrs.</p> <p>Mean $\pm$SD duration of symptoms: 38.3 $\pm$34.2 months</p> <p>No Exercise group (N= 30) - (4 men; 26 women); Mean $\pm$SD age: 43.9 $\pm$9.8 yrs.</p> <p>Mean $\pm$SD duration of symptoms: 27.7 $\pm$41.0 months</p>	<p>3 weekly sessions for 8 wks. with full supervision</p> <p>Setting: Clinical (kinesiology laboratory)</p>	<p>3 weekly sessions for 8 wks. with full supervision</p> <p>Setting: Clinical (kinesiology laboratory)</p> <p>No exercise group: (N=30)</p> <p>Given health educational materials on PFP self-efficacy</p> <p>Advised not to enrol in any exercise program during the study period</p>	<p>Follow-up: Immediately and at 8 wks. post-intervention</p>	<p>LP group:</p> <p>Significant improvements in VAS-W ratings ($p < 0.005$) with mean difference of 2.58 (3.56-1.61) and Tegner Lysholm scale ($p < 0.005$) with a mean score difference of 10.93 (7.27-14.59; 95% CI).</p> <p>Non-exercise group had no significant pain improvements ($p = 0.714-0.715$)</p> <p>Effect difference between LPHA and LP was not significant in VAS-W ratings ($p = 0.577$) and TLKSS ($p = 0.776$), respectively</p>
<p>Fukuda et al. (2010)</p> <p>Randomised controlled clinical trial</p>	<p>N=54 (females) Sedentary women</p> <p>with a confirmed diagnosis of PFP</p> <p>Age range: 20-40 yrs.</p> <p>Knee and hip Exercise (KHE) group (N=25);</p> <p>Mean $\pm$SD age: 22 $\pm$3 yrs.</p> <p>Mean $\pm$SD duration of symptoms: 23.2 $\pm$19.0 months</p>	<p>KHE group (N= 25)</p> <p>Knee exercise coupled with hip abductor and lateral rotator strengthening</p> <p>Exercise protocol included hip abduction against elastic band while standing or with weights in the side-lying position.</p> <p>Hip lateral rotation against elastic band while seated and hip extension.</p> <p>It was coupled with knee exercise for the KE group.</p> <p>3 sessions per week for 4 weeks</p> <p>Setting: Rehabilitation facility.</p>	<p>KE group (N=24)</p> <p>Hamstrings/plantar flexors/quadriceps/ iliotibial band stretches.</p> <p>Knee extension at an angle of 90° to 45°,</p> <p>Leg presses and squats at an angle of 0° to 45°, single-leg calf raises, and prone knee flexion</p> <p>3 sessions per week for 4 weeks</p> <p>Setting: Rehabilitation facility.</p>	<p>Pain assessed by 11-point NPRS during ascending and descending stairs</p> <p>Knee function assessed by LEFS and AKPS</p> <p>Follow-up: at 3, 6, and 12 months post-intervention</p>	<p>Within KHE group change in mean NPRS scores:</p> <p>For ascending stairs at 3, 6 and 12 months post-treatment were -5.0 ± 1.5 (95% CI: $-5.6, -4.4$), -4.5 ± 1.4 (95% CI: $-5.0, -4.0$) and -3.3 ± 1.1 (95% CI: $-3.7, -2.9$), respectively; ($p < .05$).</p> <p>For descending stairs at 3, 6 and 12 months post-treatment were -4.2 ± 1.7 (95% CI: $-4.9, -3.5$), -3.8 ± 1.4 (95% CI: $-4.4, -3.2$), and -3.3 ± 1.1 (95% CI: $-3.7, -2.9$), respectively; ($p < .05$).</p> <p>Within KE group change in mean NPRS scores:</p> <p>For ascending stairs at 3, 6 and 12 months post-treatment were -1.3 ± 1.2 (95% CI: $-2.9, 0.3$), -1.1 ± 1.1 (95% CI: $-1.6, -0.6$) and -0.1 ± 1.0 (95% CI: $-$</p>

					<p>0.7, 0.5), respectively: (p<.05).</p> <p>For descending stairs at 3, 6 and 12 months post-treatment were -1.4 ± 0.9 (95% CI: $-1.7, -1.1$), -0.8 ± 0.9 (95% CI: $-1.2, -0.4$), and 0.0 ± 0.9 (95% CI: $-0.3, 0.3$), respectively.</p> <p>Within KHE group change in mean LEFS scores: at 3, 6 and 12 months post-treatment were 22.4 ± 10.5 (95% CI: $18.4, 26.4$), 20.7 ± 11.0 (95% CI: $16.5, 24.9$), and 17.9 ± 9.7 (95% CI: $14.2, 21.6$), respectively: (p<.05).</p> <p>Within KE group change in mean LEFS scores: at 3, 6 and 12 months post-treatment were 0.4 ± 5.2 ($-1.7, 2.5$) -1.3 ± 5.3 ($-3.4, 2.1$) -2.9 ± 4.9 ($-4.9, -0.9$), respectively.</p> <p>For descending stairs at 3, 6 and 12 months post-treatment were -1.4 ± 0.9 (95% CI: $-1.7, -1.1$), -0.8 ± 0.9 (95% CI: $-1.2, -0.4$), and 0.0 ± 0.9 (95% CI: $-0.3, 0.3$), respectively: (p<.05).</p> <p>Within KHE group change in mean AKPS scores: at 3, 6 and 12 months post-treatment were 19.8 ± 9.1 (95% CI: $16.2, 23.4$), 15.8 ± 8.1 (95% CI: $12.6, 19.0$) and 13.1 ± 8.3 (95% CI: $9.8, 16.4$), respectively: (p<.05).</p> <p>Within KE group change in mean AKPS scores: at 3, 6 and 12 months post-treatment were 2.8 ± 8.9 (95% CI: $-0.7, 6.3$) 0.2 ± 8.4 (95% CI: $-3.2, 3.6$), and -1.8 ± 8.4 (95% CI: $-5.1, 1.5$), respectively: (p<.05).</p> <p>*Overall KHE outcomes were superior over those of the KE group (p<.05).</p>
<p>Dolak et al. (2011)</p> <p>Randomised Clinical Trial</p>	<p>N=33; Females with a confirmed diagnosis of PFP.</p> <p>Age range: 16-35 yrs.</p> <p>Hip group (N=17) Mean age: 25 ± 5 yrs.</p> <p>Mean $\pm$SD duration of</p>	<p>Hip group (n=17)</p> <p>Hip protocol involved combined hip abduction and external rotation in side-lying and standing positions coupled with seated hip external rotation.</p> <p>Participants supervised during 1 session and unsupervised during 2 weekly home-based sessions for 4 weeks.</p>	<p>Quadriceps group (n=16)</p> <p>Quadriceps protocol involved quad sets, short-arc quads, straight leg raises and terminal knee extensions</p> <p>This protocol performed for 4 consecutive weeks with full supervision.</p> <p>Setting: Rehabilitation facility and home.</p>	<p>Pain: VAS-W</p> <p>Function: LEFS, AKPS</p> <p>Follow-up: Immediately</p> <p>Outcome measured at baseline and 4</p>	<p>Hip group exhibited significant improvements in pain: 47.9% (p<0.001) and knee function: 18.7% (p<0.001).</p> <p>Quadriceps group exhibited significant improvements in knee function (9.3%; p<0.001) but not pain (p=0.88)</p> <p>Pain significantly reduced in the hip group</p>

	<p>symptoms: 36 ±34 months</p> <p>Quadriceps group (n=16) Mean age: 26±6 yrs.</p> <p>Mean ±SD duration of symptoms: 27±34 months</p>	<p>Setting: Rehabilitation facility and home</p>		<p>weeks post-intervention</p>	<p>compared to the quadriceps group with a mean difference of 1.7 (p=0.035)</p> <p>No significant difference in knee function (p>0.05) between the two groups at the end of the study.</p>
<p>Fukuda et al. (2012)</p> <p>Randomised controlled trial with 1-year follow-up.</p>	<p>N=49; Sedentary females with a confirmed diagnosis of PFP</p> <p>Age range 20-40 yrs.</p> <p>Hip/quadriceps group (n=25) Mean ±SD age: 22.0 ±3.0 yrs.</p> <p>Mean ±SD duration of symptoms: 23.2 ±19.0 months</p> <p>Quadriceps group (n=24) Mean ±SD age: 23.0 ±3.0 yrs.</p> <p>Mean ±SD duration of symptoms: 21.0 ±17.7 months</p>	<p>Hip/quadriceps group (N=25)</p> <p>Hip abductor and external rotators coupled with quadriceps strengthening/stretching knee exercise: seated knee extension, leg press, squatting, stretching of hamstrings, quadriceps, ankle plantar flexors and iliotibial band</p> <p>3 sessions per week for 4 weeks</p> <p>Setting: Rehabilitation facility.</p>	<p>Quadriceps group (N=24)</p> <p>Quadriceps strengthening/stretching knee exercise; seated knee extension, leg press, squatting, stretching of hamstrings, quadriceps, ankle, plantar flexors and iliotibial band</p> <p>Setting: Rehabilitation facility.</p>	<p>Pain: 11-point NPRS during ascending and descending stairs</p> <p>Function: LEFS, AKPS</p> <p>At baseline</p> <p>Follow-up: immediately and post-intervention at 3, 6, and 12 months.</p>	<p>For interventional group:</p> <p>Pain during upstairs gait reduced to 80.7% (p <0.05) at 3 months, 73.2% (p <0.05) at 6 months and 53.2 % (p <0.05) at 12 months</p> <p>Pain during downstairs gait reduced to 72.4 % (p <0.05) at 3 months, 65.5 % (p <0.05) at 6 months and 56.9 % (p <0.05) at 12 months</p> <p>Knee function score on AKPS improved to 30.1 % (p <0.05) at 3 months, 20.4 % (p <0.05) at 6 months and 19.9 % (p <0.05) at 12 months</p> <p>For comparator group:</p> <p>Pain during downstairs gait reduced to 21.9% (p <0.05) at 3 months, 12.5% (p <0.05) at 6 months.</p> <p>At 6 months pain during upstairs gait reduced to 16.7% (p <0.05)</p> <p>No significant change in both AKPS and LEFS scores at 3, 6 and 12 months.</p>
<p>Khayambashi et al. (2012)</p> <p>Randomised controlled trial.</p>	<p>N= 28; Sedentary females with patellofemoral pain (PFP)</p> <p>Hip exercise group (n=14); Mean ±SD age: 28.9±5.8 yrs.</p> <p>Duration of symptoms: not indicated</p> <p>Non-exercise group (N=14); Mean ±SD age: 30.5 ±4.8 ±3.2 yrs.</p> <p>Duration of symptoms: not indicated</p>	<p>Hip exercise group (n=14)</p> <p>Supervised isolated hip abductor strengthening to 30° in standing position.</p> <p>Supervised isolated hip external rotator strengthening to 30° in the seated position.</p> <p>Exercise protocol performed 3 times per week for 8 weeks.</p> <p>Setting: Rehabilitation facility.</p>	<p>Non-exercise group (n=14)</p> <p>Participants also prescribed 1000 mg of Omega-3 and 400 mg of calcium daily for 8 weeks.</p> <p>Setting: home</p>	<p>Worst pain in the previous week assessed by VAS</p> <p>Self-reported health status assessed by the Western Ontario and McMaster Universities (WOMAC) questionnaire.</p> <p>VAS and WOMAC scores recorded at baseline (pre-intervention), week 8 (post-intervention), and 6 months post-intervention.</p>	<p>For hip exercise group:</p> <p>Exhibited significant improvements in VAS score (p <0.001):</p> <p>Mean VAS score difference from baseline (7.9 ±1.7) to 8 wk. post-intervention (1.4 ±1.9) was -6.4 ±2.7; 95% CI: -7.9, -4.9 (p <0.001).</p> <p>Mean VAS score difference from baseline (7.9±1.7) to 6 months post-intervention (1.7±2.7) was -6.2 ±1.4; 95% CI: -7.9, -4.3 (p <0.001).</p> <p>Significant improvements were seen in WOMAC score (p <0.001):</p>

					<p>Mean WOMAC score difference from baseline (54.0±18.1) to 8 wk. post-intervention (10.7±16.1) was -43.3 ±20.1; 95% CI: -54.9, -31.7 (p<0.001).</p> <p>Mean WOMAC score difference from baseline (54.0±18.1) to 6 months post-intervention (10.8 ±17.7) was -43.2 ±7.7; 95% CI: -55.9, -30.0 (p <0.001).</p> <p>Non-exercise group:</p> <p>No noticeable improvements in VAS and WOMAC scores (p >0.05).</p>
<p>Ismail et al. (2013)</p> <p>Prospective randomised controlled trial</p>	<p>N=32; (23 females 9 males); with a confirmed diagnosis of PFP</p> <p>Age range 18-30 yrs.</p> <p>Closed kinetic chain (CKC) + hip exercise (CKCH) group (n=16); (11 women, 5 men)</p> <p>Mean ±SD age: 20.8 ±2.7 yrs.</p> <p>Mean ±SD duration of symptoms: not indicated</p> <p>CKC group (n=16); (12 women, 4 men)</p> <p>Mean ±SD age: 21.2 ±3.2 yrs.</p> <p>Mean ±SD duration of symptoms: not indicated</p>	<p>CKCH group (n=16)</p> <p>Hip abductors and lateral rotators strengthening exercise coupled with CKC exercises for hip/quadriceps strengthening</p> <p>Hip abductor strengthening performed in a side-lying position on the non-affected side.</p> <p>Lateral rotators strengthening performed while seated and hip flexed to 90°</p> <p>Training sessions: 3 times per week for 6 weeks</p> <p>Setting: Rehabilitation facility.</p>	<p>CKC group (n=16)</p> <p>Closed kinetic chain exercises for quadriceps strengthening</p> <p>Protocol involved stretching of hamstrings, iliotibial band and gastrocnemius.</p> <p>Also involved mini wall squats, forward/lateral step-ups and terminal knee extensions.</p> <p>Training sessions: 3 times per week for 6 weeks</p> <p>Setting: Rehabilitation facility.</p>	<p>Worst pain in the previous week assessed by VAS</p> <p>Knee function assessed by AKPS</p> <p>Follow-up: Immediately</p> <p>Outcome measured at baseline and 6 weeks post-intervention</p>	<p>For CKCH group:</p> <p>Significant improvements in VAS and Kujala scores (p <0.05).</p> <p>Mean VAS score difference from baseline (5.3 ±1.6) to 6 wk. (2.0 ±1.1) post-intervention 3.2 ±0.9.</p> <p>Mean Kujala score difference from baseline (71.5 ±7.8) to 6 wk. (85.1 ±6.2) post-intervention 13.7 ±5.5</p> <p>For CKC group:</p> <p>Significant improvements in VAS and Kujala scores p <0.05)</p> <p>Mean VAS score difference from baseline (4.5 ±1.8) to 6 wk. (2.3 ±1.1) post-intervention 2.26 ±1.3.</p> <p>Mean Kujala score difference from baseline (76.4 ±10.4) to 6 wk. (85.0 ±6.7) post-intervention 8.6 ±7.3</p> <p>*Overall pain and function outcome in the CKCH group was superior to the CKC group (p <0.05)</p>
<p>Baldon et al. (2014)</p> <p>Randomised, comparative-controlled single-blinded study</p>	<p>N=31 (Females); with a confirmed diagnosis of PFP</p> <p>Age range: 18-30 yrs.</p> <p>Hip exercise group (n=15); Mean ±SD age: 27.7±3.2 yrs.:</p> <p>Mean duration of symptoms:</p>	<p>Hip exercise group (n=15)</p> <p>Hip extension/lateral rotation in prone, side-lying, standing</p> <p>Isometric hip abduction/lateral rotation in standing knee and hip flexion in side-lying</p> <p>Pelvic drop in standing</p>	<p>Quadriceps group (n=16)</p> <p>Quadriceps strengthening and lateral retinaculum stretches</p> <p>Hamstrings, soleus, gastrocnemius, and iliotibial band stretches</p> <p>Sessions performed 3 times a week for 8 wks.)</p> <p>Sessions lasted between 75 to 90 minutes with</p>	<p>Worst-pain in the previous week rated on 10cm- VAS</p> <p>Knee function: LEFS</p> <p>Baseline, immediately and 3-month post-intervention</p>	<p>For Hip exercise group:</p> <p>Mean differences in VAS score at end of intervention (-5.2 ±1.6) and 3-months post-intervention (-5.7 ±2.3) were significant (p<0.05*). Pain reduced.</p> <p>Mean difference in LEFS at end of intervention (-18.9 ±12.5) and 3-months post-intervention -19.5 ±11.9) were significant (p</p>

	<p>not indicated</p> <p>Quadriceps group (n=16); Mean $\pm$SD age:21.3$\pm$2.6 yrs.:</p> <p>Mean duration of symptoms: not indicated</p>	<p>Hip lateral rotation in closed kinetic chain</p> <p>Plus the standard knee exercise</p> <p>Sessions performed 3 times a week for 8 wks.)</p> <p>Sessions lasted between 90 to 120 minutes with supervision by a physical therapist</p> <p>Setting: Laboratory of Intervention and Orthopaedics and Traumatology laboratory</p>	<p>supervision by a physical therapist</p> <p>Setting: Laboratory of Intervention and Orthopaedics and Traumatology laboratory</p>	<p><0.05*). Knee function improved</p> <p>For quadriceps group:</p> <p>Pain improved significantly (p <0.05), but not knee function (p >0.05).</p> <p>Mean difference in VAS at the end of intervention (– 3.0 $\pm$ 2.4) and 3-months post-intervention (– 3.6 $\pm$ 3.3) were significant (p <0.05).</p> <p>Mean difference in LEFS score at the end of intervention (– 12.9 $\pm$ 7.5) and 3-months post-intervention (– 12.7 $\pm$ 6.2) was not significant (p >0.05).</p> <p>Between-group difference in VAS scores only significant at 3-months post-intervention (p <0.05).</p> <p>Between-group differences not significant in VAS at any time-point</p>
<p>Khayambashi et al. (2014)</p> <p>Comparative control trial</p>	<p>N=36 (18 men, 18 women); with clinical diagnosis of PFP</p> <p>Hip exercise group (n=18); (9 men and 9 women); Mean $\pm$SD age: 28.2 $\pm$ 7.9 yrs.</p> <p>Mean duration of symptoms: not indicated</p> <p>Quadriceps group (n=18); (9 men and 9 women); Mean $\pm$SD age: 27.3 $\pm$ 6.7yrs</p> <p>Mean duration of symptoms: not indicated</p>	<p>Hip exercise group (n=18)</p> <p>Underwent supervised exercise programs targeting hip muscles strengthening.</p> <p>Hip exercise protocol included hip abductor and external rotator strengthening exercises in side-lying and knee flexed to 90° while seated, respectively.</p> <p>Quadriceps protocols include knee flexion to 30°coupled with partial squats.</p> <p>3 times a week for 8 wks.</p> <p>Setting: Rehabilitation facility</p>	<p>Quadriceps group (n=18)</p> <p>Received supervised quadriceps strengthening exercises (3 times a week for 8wks).</p> <p>Quadriceps protocols included knee flexion to 30° coupled with partial squats.</p> <p>Setting: Rehabilitation facility</p>	<p>Worst pain in the previous week assessed by VAS</p> <p>Self-reported health status assessed using the WOMAC questionnaire.</p> <p>VAS and WOMAC scores recorded at baseline (pre-intervention), week 8 (post-intervention), and 6 months post-intervention.</p> <p>For Hip exercise group:</p> <p>Significant improvements in VAS and WOMAC scores (p <0.001):</p> <p>Mean VAS score difference from baseline (7.63 $\pm$ 1.79) to 8 wk. (2.11 $\pm$ 1.6) and 6 months (2.00 $\pm$ 1.97) post-intervention was –5.53 $\pm$ 1.60; 95% CI and –5.64 $\pm$ 1.99; 95% CI, respectively (p <0.001).</p> <p>Mean WOMAC score difference from baseline (46.83 $\pm$ 21.86) to 8 wk. (6.22 $\pm$ 3.87) and 6 months (6.94 $\pm$ 5.70) post-intervention was –40.61 $\pm$ 20.68; 95% CI and –39.89 $\pm$ 21.35; 95% CI, respectively (p <0.001).</p> <p>For Quadriceps group:</p> <p>Significant improvements in VAS and WOMAC scores (p <0.001):</p> <p>Mean VAS score difference from baseline (6.91 $\pm$ 1.94) to 8 wk. (3.27 $\pm$ 2.19) and 6 months (4.00 $\pm$ 2.44) post-intervention was –3.64 $\pm$ 1.39; 95% CI and –2.92 $\pm$ 1.72; 95% CI, respectively (p <0.001).</p> <p>Mean WOMAC score difference from baseline (44.11 $\pm$ 22.05) to 8 wk.</p>

(21.89 ±16.55) and 6 months (23.16 ±14.15) post-intervention was – 22.22 ±10.59; 95% CI and –20.94 ±14.30; 95% CI, respectively (p <0.001).

*Between-group difference was statistically significant p ≤0.05, where outcomes in the hip group were superior over the quadriceps group.

Table 6: Descriptions and critique of the reviewed 10 controlled clinical trials (CCTs)

Authors	Study design	level of evidence	critique
Avraham et al., 2007	RCT	Level 2b	<ul style="list-style-type: none"> ✓ Inadequate sample size (pilot study) ✓ Participants were not truly randomized to the three intervention groups ✓ Allocation concealment probably not done ✓ The physiotherapist who assessed the patients was blinded to the study ✓ Blinding of outcome assessment achieved by using patient-reported outcomes on VAS for patellofemoral pain ✓ Evaluation scale PES
Baldon et al., 2014	RCT	level 1b	<ul style="list-style-type: none"> ✓ Participants recruited a/c to sample power estimation ✓ Participants were truly randomized by random sequences in a block randomization manner ✓ Allocation concealment evident ✓ Double blinding evident (participants and therapists) ✓ Blinding of outcome assessment evident because the only patient-reported pain and function outcomes collected.
Dolak et al., 2011	RCT	level 2b	<ul style="list-style-type: none"> ✓ Inadequate sample power ✓ Participants truly randomized by random sequence or block randomization ✓ Allocation concealment evident with a random number ✓ Outcome assessors partially blinded to participants (probable detection bias) ✓ Outcome assessment blinded (the only patient-reported pain and function outcomes recorded).
Fukuda et al., 2010	RCT	level 1b	<ul style="list-style-type: none"> ✓ Participants recruited a/c to sample power calculation ✓ Participants truly randomized ✓ Allocation concealment not evident ✓ Therapists not blinded ✓ Incomplete outcome data managed by intention-to-treat analysis ✓ Outcome assessment blinded (the only patient-reported pain and function outcomes recorded).
Fukuda et al., 2012	RCT	level 1b	<ul style="list-style-type: none"> ✓ Participants recruited based on the calculated sample power ✓ Participants were truly randomized ✓ Allocation concealment not evident ✓ Therapists not blinded ✓ Incomplete outcome data managed by intention-to-treat analysis ✓ Outcome assessment blinded (the only patient-reported pain and function outcomes recorded).
Ismail et al., 2013	RCT	Level 2b	<ul style="list-style-type: none"> ✓ Inadequate sample power (Estimated sample power size not followed) ✓ Random allocation of participants concealed ✓ Therapists and assessors blinded to group allocation details ✓ Outcome assessment blinded (the only patient-reported pain and functional outcomes)
Khayambashi et al. 2014	CCT	Level 2b	<ul style="list-style-type: none"> ✓ Inadequate sample power ✓ Participants not allocated to restive groups by random allocation ✓ Participants and therapists not blinded ✓ Outcome assessment blinded (the only patient-reported pain and functional outcomes)

Khayambashi et al. 2012	RCT	Level 2b	<ul style="list-style-type: none"> ✓ Inadequate sample power ✓ Participants random allocation not followed ✓ Participants and therapists not blinded ✓ Outcome assessment blinded (the only patient-reported pain and functional outcomes)
Nakagawa et al., 2008	RCT-p	Level 2b	<ul style="list-style-type: none"> ✓ Inadequate sample size (pilot study) ✓ Group allocation concealed using sealed envelopes ✓ Therapist not blinded ✓ Principle investigator partially blinded (only at baseline phase) ✓ Blinded assessors employed
Song et al., 2009	RCT	level 1b	<ul style="list-style-type: none"> ✓ Participants randomized to group ✓ Participants and therapists blinded

RCT, randomised controlled trial; CCT, comparative control trial; RCT-p, randomised controlled pilot study; CS, cohort study; CSr, case series

Table 7: Evidence table for follow-up studies (cohort, case-control, case series and case reports)

Authors Study design	Patient sample size & characteristics	Description of interventions and setting	Comparator exercise and setting	Follow-up duration & outcome measures	Effect size & summary of key findings
Boling et al. (2006) Pre-test and post-test 6-week intervention cohort study	N=28; Participants with and without PFP. Age range: 18-42 yrs. Experimental group (n=14) participants with a confirmed diagnosis of PFP (5 men, 9 women) Mean $\pm$ SD age: 24 $\pm$ 6 yrs. Mean $\pm$ SD duration of symptoms: 22 $\pm$ 25 months Control group (n=14) healthy participants (5 men and 9 women) Mean $\pm$ SD age: 23 $\pm$ 2 yrs.	All participants received weight-bearing exercises focusing on strengthening of hip abductors, gluteus medius, and quadriceps strengthening coupled with lower-extremity neuromuscular control for 6 weeks. Setting: Musculoskeletal research laboratory	N/A	VAS and Functional Index Questionnaire (FIQ) administered at pre-test and post-test and the end of every week of the 6-wk intervention.	At the end of the intervention, the PFP participants exhibited significant improvements in both VAS ($p=0.001$) and FIQ ($p=0.001$) scores from the baseline. Based on Post hoc analyses, no significant changes in both VAS and FIQ scores were observed in the control group.
Ferber et al. (2011) Cohort study (Pre-test and post-test)	N=25; Participants with and without PFP. Experimental group (n=15) participants with a confirmed diagnosis of PFP (5 men, 10 women) Mean $\pm$ SD age: 35.2 $\pm$ 12.2 yrs Mean duration of symptoms not indicated. Control group (n=10) Healthy participants (4 men and 6 women) Mean $\pm$ SD age: 29.9 $\pm$ 8.3 yrs Mean duration of symptoms not indicated.	Experimental group completed a 3-week exercise training targeting the strengthening of hip-abductor muscles. Setting: University-based clinical research laboratory	No exercises	Hip abductor muscle strength and pain (VAS) measured at baseline and after 3-week training.	3-week hip-abductor muscle-strengthening protocol administered to participants with PFP was effective in increasing isometric muscle strength, which improved by 32.69% from baseline ($p=0.04$). Mean difference between pre-training and post-training VAS scores was 3.30 $\pm$ 1.90, ($p=0.01$) which translated into 43.10% reduction in VAS score.
Earl & Hoch, (2011). Case series; Level of evidence, 4	N=19; Women with a confirmed diagnosis of PFP Age range 16-40 yrs.	Completed 8-weeks exercise program targeting hip and core muscles strengthening and improving dynamic malalignment. Exercises were administered in 3 phases: Phase I: Abdominal draw-in exercises, side-lying clamshells /straight-leg	N/A	Pain and function assessed at baseline, 8 weeks and 6 months post-training Pain assessed by VAS	Significant improvements in pain and functional ability ($p<0.0005$). Effects lasted at least 6 months post-rehabilitation.

(with Pre-test and post-test design)	Mean $\pm$ SD age: 22.68 $\pm$ 7.19 yrs. Mean duration of symptoms: 17 months (range, 1-60 months).	raises, supine arm/leg extensions, quadruped leg extensions, isometric single-legged stance (SLS), quadriceps/ hamstring/calf stretches Phase II: Isometric SLS with hip abduction, SLS quick kicks, prone/side planks, quadriceps/ hamstring/calf/iliotibial band stretches. Phase III: Monster walks, SLS, quadriceps/hamstring/calf/iliotibial band stretches Setting: Both at research laboratory and rehabilitation facility settings.		Function assessed by AKPS	
Tyler et al. (2006) Cohort study; Level of evidence, 2 (with Pre-test and post-test design)	N=35; Participants with and without PFP (6 men; 29 women) Mean $\pm$ SD age: 33 $\pm$ 16 yrs. Mean duration of symptoms: not recorded	All participants underwent 6-week partially supervised exercise program targeting strengthening of hip and knee muscles. Exercise protocol involved seated hip flexion, adduction, extension, abduction; Stretching of hip flexors, quadriceps, iliotibial band. Setting: rehabilitation centre supplemented with a home exercise program manual	N/A	Pain and knee discomfort during normal activities of daily living and exercise were assessed by VAS	Mean VAS score during normal daily activities improved from 4.9 $\pm$ 0.3 to 2.7 $\pm$ 0.3 (p < 0.001) Mean VAS score during exercise also improve from 5.8 $\pm$ 0.4 to 3.0 $\pm$ 0.4 (p< 0.001).

Figures

Figure 1

PRISMA flow chart for articles search strategy, screening and eligibility evaluation

Figure 2

Hip versus quadriceps strengthening on PFP

Figure 3

Comparative effect of hip versus quadriceps strengthening on knee function

Surplus effect of hip-quadriceps Vs. quadriceps strengthening on PFP (Meta-analysis)

Figure 4

Hip-quad strengthening results in significant pain improvements compared to the standard quadriceps strengthening alone.

Figure 5

Hip-quad strengthening resulted in a greater functional improvement than the standard quadriceps strengthening alone.

Supplementary Files

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- [PRISMA2020checklist.pdf](#)