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REVIEW

Trunk, Hip and Knee Exercise Programs for Pain Relief, Functional Performance and Muscle Strength in Patellofemoral Pain: Systematic Review and Meta-Analysis

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Objective: Previous research suggests that muscle strength exercise is the most effective rehabilitation methods in patients with patellofemoral pain (PFP). This systematic review with meta-analysis compared the effects of Hip&Knee, Hip-only and Knee-only exercise programs on pain relief, muscle strength, and functional performance in patients with PFP.

Methods: Literature searches of PubMed, PEDro and CINAHL databases revealed twenty-one studies included in the final descriptive review, thirteen of which were included in the meta-analysis. Data extraction included baseline and post-intervention means and standard deviations of all eligible outcome measures both for the intervention and control groups, participants baseline demographics and intervention characteristics.

Results: The results showed that Hip&Knee and Hip-only exercise programs were comparatively effective, while the Knee-only exercise programs proved to be inferior to the above-mentioned approaches. The Hip&Knee exercise programs showed the greatest pain relief (mean difference = −1.71 (−3.11, −0.30); $p = 0.02$; $I^2 = 96\%$) and functional improvement (standardized mean difference = 1.28 (0.45, 2.12); $p = 0.003$; $I^2 = 84\%$), although the subgroup analysis did not show any significant difference compared to Hip-only exercise programs ($p > 0.05$).

Conclusion: Overall, Hip&Knee exercise programs appear to reduce pain and improve function more than other exercise programs and could be used as a primary rehabilitation approach in patients with PFP. However, the difference between the subgroups in most outcome measures suggests that Hip&Knee exercise programs are no more effective than Hip-only exercise programs.

Keywords: patellofemoral pain, exercise, function, strength

Introduction

Patellofemoral pain (PFP) is characterized as pain around, behind, or under the patella during activities that increase the stress on the patellofemoral joint (PFJ), such as squatting, running, prolonged sitting with knees flexed, stair climbing or jumping.[1] This is one of the most common forms of knee and lower extremity pain, with an annual prevalence of 23% in the general population and 29% in adolescents.[2] Although there is no definitive clinical test for the diagnosis of PFP, squat maneuvering has been reported to trigger PFP in 80% of patients, while palpation of the patellar ligaments triggers PFP in up to 75% of patients.[3] In the

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past, the cause of PFP was primarily sought in the performance of the quadriceps muscle, as local imbalances between the muscles in the knee area can contribute to increased PFJ load.[4,5] While the etiology of PFP has not been yet fully clarified, recent studies are largely based on the assumption that both proximal (femur) and distal (tibia) segments have a significant influence on patellar movement and thus on PFP. Altered patellar movement may be due to several anatomical, biomechanical and behavioural factors, although the primary factor contributing to PFP is still unclear.[6] Traditionally, research has focused on local factors contributing to increased stress on the PFJ, such as imbalances between the vastus medialis oblique and the vastus lateralis muscles[5] as well as overall strength deficits of the quadriceps muscle.[7] Recently, however, hip muscle strength deficits have emerged as an important factor widely present in patients with PFP. Reduced strength of the hip abductors and external rotators can lead to lower extremity malalignment and increased stress on the PFJ.[8,9] Thus, it is assumed that the reduction in PFP following hip muscle strengthening exercise programs is directly related to the improvement of biomechanical changes in the knee area.[10] However, studies comparing the effectiveness of knee exercise programs to hip exercise programs are inconclusive and further research is required.[11]

Given the aforementioned factors regarding the reduced strength of hip muscles, it is not surprising that many exercise programs focus on improving the maximal voluntary isometric contraction (MVIC) of the trunk, hip or knee muscles. Positive effects of the exercise programs targeting muscle groups adjacent to the knee have been reported by several authors,[12–16] although not all have shown to be effective.[17,18] More importantly, even with numerous studies conducted with the aim of comparing different exercise program for patients with PFP, it is still not clear which approach is the most effective. Such ambiguity can result in a more time-consuming clinical practice, as clinicians often prescribe traditional, knee-only exercise programs regardless of their actual effectiveness. It is believed that the main reason for this uncertainty is in strengthening both hip and knee muscle groups in the same exercise program.[11,19,20] As a result, difficulties are arising in determining the actual effects of isolated hip or knee muscle strengthening on PFP. A review concerning the rehabilitation of patients with PFP focusing on resistance exercise of hip versus knee muscles concluded that hip muscle strengthening is effective in reducing pain and improving function.[21] However, high variability in the protocol type, used methods and outcome measures limited the pooling of data. Therefore, it is necessary to update the clinical guidelines for reducing pain and improving function in patients with PFP. Moreover, several new studies investigating the effects of strengthening the hip muscle on PFP were published since the latest systematic review.[21]

Our systematic review with meta-analysis aims to assess the effects of exercise programs focusing on training of muscle groups proximal to the knee in patients with PFP. Hip&Knee exercise programs were defined as progressive exercise directed to the hip and knee muscle groups, while Hip-only or Knee-only exercise programs were defined as progressive exercise directed only to the hip or knee muscle groups. We hypothesized that such exercise programs are effective in reducing pain levels, enhancing functional improvements and proximal muscle strength improvements in patients with PFP.

Methods

Search Strategy

The systematic review with meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis statement.[22] The search for relevant articles was conducted in September 2020 using the PubMed, PEDro and CINAHL databases. We limited our search to papers published in English language. The following search strategy was used: (*patell* OR anterior knee) AND (pain OR syndrome) AND ((hip OR proximal joint*) OR (torso OR back) OR (ankle OR foot)) AND (movement OR function) AND (physioth* OR physical) AND therapy. In addition, various keywords combinations, including, but not limited to anterior knee pain, patellofemoral pain (syndrome), exercise therapy, exercise intervention, proximal rehabilitation were used. Additionally, the lists of references of articles already found by the search of databases were reviewed. Finally, all possible admissible studies were obtained and reviewed in full text.

Inclusion and Exclusion Criteria

The PICOS tool was used to structure and organize the study inclusion criteria:[23]

- Population (P): Females and males without age or activity level restriction, described as patients with

PFP or anterior knee pain. Studies investigating other knee pathologies were excluded.

- Intervention (I): Exercise programs focusing on muscle groups proximal to the knee, regardless of their duration, alone or in combination with quadriceps exercise programs. Proximal muscle exercise programs were determined as progressive exercise focusing on the trunk or hip muscle groups. Studies evaluating multimodal exercise programs were included on the condition that the effects of including exercise programs focusing on muscle groups proximal to the knee could be determined.
- Comparison (C): Patients without relevant interventions or patients that received isolated quadriceps muscle exercise programs. Studies in which patients underwent any type of invasive rehabilitation method, eg, surgery or injections, were excluded. Also, studies including orthoses, taping or bracing of any kind were excluded.
- Outcomes (O): a) Pain measured using the Visual Analogue Scale (VAS), b) functional outcomes questionnaire (Anterior Knee Pain Scale, AKPS; Lower Extremity Functional Scale, LEFS; Western Ontario and McMaster Universities Arthritis Index, WOMAC) and c) MVIC of trunk, hip or knee muscles.
- Study design (S): Randomized control trials (RCT) including a minimum of one intervention and control group as well as evaluating adjacent muscle exercise programs were included.

Eligible studies were finally screened by two reviewers in order to reach an agreement regarding the study inclusion. The third reviewer was available for consultation in case of any discrepancies.

Data Extraction

Data extraction included baseline and post-intervention means and standard deviations (SD) for all outcome measures under consideration for the intervention and control groups. The extracted data also included patients' demographics (age, gender, body height and mass, body mass index). Furthermore, basic intervention characteristics were extracted. These included muscle group involvement, duration of intervention in weeks, weekly frequency, the duration of breaks allowed before the next exercise or between sets, guidance and supervision during the intervention, exercise progression and compliance to the exercise program. Data extraction also included the type of used load (machine, bodyweight, free weights and elastic bands). The intensity of exercise, expressed as a percentage of one-repetition maximum or by subjective measures, such as the Borg scale, was extracted. The corresponding authors of respective studies were contacted via e-mail in case of missing data. Data was then imported in MS Excel 2019 (Microsoft, Redmond, USA). In cases where the data was presented in a graphical form, Adobe Illustrator Software (version CS5, Adobe Inc., San Jose, USA) was used to establish the precise value of the mean and SD. This software allows zooming in substantially on the graphs and measuring the relevant data with high precision; thus, the errors introduced by this method are negligible.

Quality Assessment

PEDro scale was used to assess the quality of the included studies, as it specifically assesses the quality of RCTs regarding physiotherapeutic interventions.[24,25] The PEDro scale is a widely used 11-item scale where each satisfied item adds one point on the overall score (range 0–10). Accordingly, a higher score indicates higher quality of the RCT. Studies were evaluated by two reviewers in order to eliminate any discrepancies. Studies scoring above 6 on were characterized as high quality (HQ), whereas those scoring 6 or below were considered low quality (LQ) studies.[26]

Data Analysis

The main data were extracted from each study. For further analysis, we used the Review Manager program (Version 5.4. The Cochrane Collaboration, 2020). Prior to entering the data into the meta-analytical model, the following formula was used to calculate the SD and the pre-post differences: $SD = \sqrt{[(SD_{pre}^2 + SD_{post}^2) - (2 \times r \times SD_{pre} \times SD_{post})}$. The pretest-posttest correlation of outcome measures is represented by the correction value (r). Since an r between 0.5 and 0.9 would not influence the analysis, it was set at 0.75. The inverse variance method was used in the meta-analysis for continuous outcomes with a random-effects model. In case of studies using comparable outcome measures (eg, VAS, AKPS, LEFS, MVIC) and evaluating similar interventions, a meta-analysis was completed. Whenever possible (VAS, AKPS, LEFS), the effect sizes were expressed as mean difference (MD) to warrant it to be expressed in measurement units (cm or points). As a result of the heterogeneity of some outcome measures (eg, muscle strength reported in Nm/kg, N/kg, kg, Nm and N), the effect size in those cases was expressed as standardized mean difference (SMD). Confidence intervals (95%) were calculated for both MD and SMD. All outcome measures except for VAS, where the improvement is presented as a decrease in centimetres (cm), were converted so that the positive outcomes (AKPS, LEFS, MVIC) were presented as positive values to facilitate consistency in visual representation. Studies with specific comparative groups, such as motor control learning or somatosensory exercises, as well as those without a comparative group were excluded from the meta-analysis. However, the results from these studies were extracted and a descriptive analysis was performed. The analysis of statistical heterogeneity, defined as $p \leq 0.05$, was performed by calculating the I^2 test. In accordance to the Cochrane guidelines,[27] the I^2 of 75% to 100% indicates considerable heterogeneity, 50% to 90% stands for substantial heterogeneity, 30% to 60% denotes moderate heterogeneity, while the I^2 below 40% may not be important. For each analysis, a forest plot was constructed, depicting mean effect with 95% confidence intervals for individual studies, and the pooled effect across studies. Sensitivity analysis was performed by eliminating individual studies, one at the time, and observing the changes in pooled effect.

Results

Summary of Search Results

The search process is presented in Figure 1. The initial database search revealed 617 items which were then checked for duplicates. The abstracts of the remaining 505 items were screened leading to 31 items suitable for full-text screening. Finally, the full-text screening revealed 21 studies (29 intervention groups in total) that were eventually included in the descriptive review, 13 of which were included in the meta-analysis. Eight studies were not included in the meta-analysis due to the lack of comparative groups or to specific comparative groups including somatosensory training, motor control training or stretching interventions.

Study Quality Assessment

According to PEDro scale, the average quality of the studies was rated as "good" (mean = 6.62 (1.39); median = 7.0; range = 4–8). None of the included studies was double-blind. One study was rated as being of "poor" quality, satisfying 3 items. Five studies scored 4–5 and were therefore rated as being of "fair" quality, whereas the remaining fifteen studies scored 6–8 and were rated as being of "good" quality. Studies with "Excellent" quality, scoring 9 or 10 on the PEDro scale, were not found. Results from the PEDro scale are summarized in Table 1.

Participant Data and Exercise Programs Characteristics

One thousand one hundred and ninety-nine patients participated in the included studies (283 in the Hip focused exercise groups; 256 in the Hip&Knee groups; 326 in the Knee groups; 246 in Control groups; 27 in the Hip&Knee&Core groups; 15 in the Functional stabilization group; 17 and 29 in the Somatosensory group with or without additional Hip&Knee exercises, respectively). The patients' mean age across the studies was 25.9 (3.7) years with the range of means from 21–34 years. The body mass index across studies was 22.8 (1.9) kg/m^2 (range of means: 19.3–25.9 kg/m^2), while the pooled patient body mass was 61.5 (6.6) kg (range of means: 47.9–71.1 kg). The pooled patient body height was 163.2 (4.5) cm (range of means: 156.9–171.1 cm). In total, nine studies included both male and female patients, twelve studies included only females while no studies including only males were found. Inclusion and exclusion criteria for each study, along with the outcome measures, compliance rate and main findings are presented in Table 2.

The details regarding exercise programs are available in Table 3. The majority of the studies (n = 19) included supervised exercise programs, while in two studies the programs were performed with no supervision. The duration of the exercise programs ranged from 3–12 weeks with the most typical duration being 6 weeks (n = 8). Fifteen studies performed the prescribed exercise programs with a frequency of three times per week, while the remaining five studies included either a lower (2 times per week) or higher (5 or 7 times a week) number of exercise sessions per week, with one study not specifying the weekly frequency. With one exception, all studies included a progression of the exercise programs. Finally, nine studies reported compliance with the exercise programs which was on average 84% (11.8%).

Regarding the type of exercise programs, nineteen studies used a combination of bodyweight exercises and additional machines or free weights, while two studies used bodyweight exercises only. Seven studies included

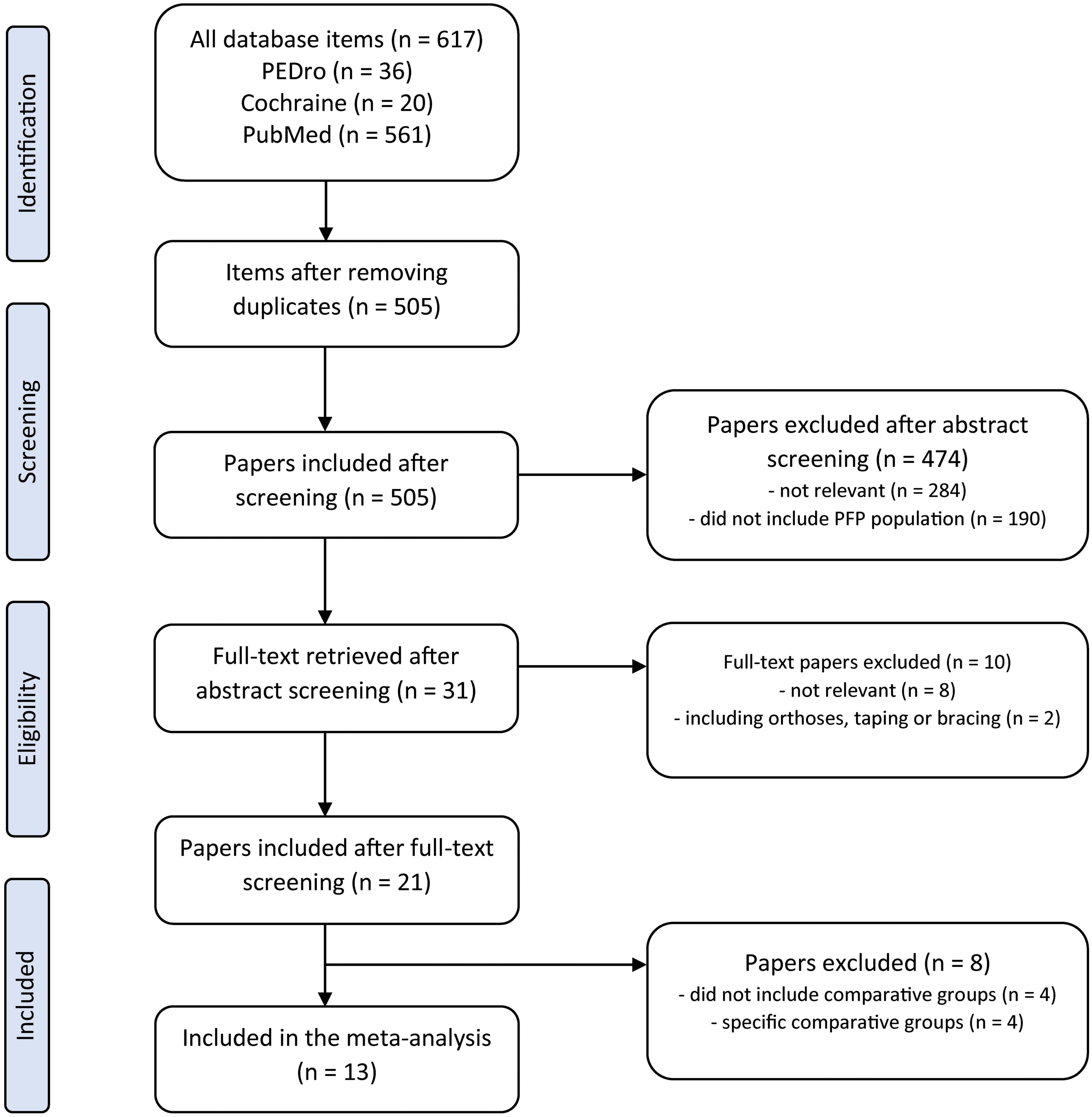

Figure 1 Search results.

resistance exercise with elastic mini-bands. In a single study, an unstable seat was used to emphasize trunk stabilization during lower body exercises. In most cases, the exercise complexity was found to be homogeneous, with seventeen studies reporting a combination of multi-joint and mixed exercises. However, there was substantial heterogeneity between the studies in terms of exercise duration and number of exercises. Eleven studies reported session duration ranging from 15–120 (mean: 42.2 (24.2)) minutes per session. Although five studies progressively increased the duration of sessions, the average duration of a single exercise session was 30 minutes. The number of exercises performed per session also varied substantially from study to study, ranging from 2–13 (mean: 4.9 (2.3)). The volume of exercise regarding the number of repetitions in most studies increased progressively, ranging from 5 to 30 (mean: 14.2 (6.5)). Similarly, the quantity of exercise sets varied from 1 to 5 (mean: 2.7

Table 1 Summary of PEDro Scale Methodological Quality of the Included Studies

Author	I	II	III	IV	V	VI	VII	VIII	IX	X	Score (/10)
Studies included in the meta-analysis											
Hott et al (2019)[17]	1	1	1	0	0	1	1	1	1	1	8
Saad et al (2018)[18]	1	1	1	0	0	1	1	1	1	1	8
Fukuda et al (2012)[10]	1	1	1	0	0	1	1	1	1	1	8
Hott et al (2020)[33]	1	1	1	0	0	1	1	1	1	1	8
Ismail et al (2013)[35]	1	1	1	0	0	1	1	1	1	1	8
Nakagawa et al (2008)[36]	1	1	1	0	0	1	1	1	0	1	7
Fukuda et al (2010)[34]	1	1	1	0	0	1	1	0	1	1	7
Dolak et al (2011)[31]	1	0	1	0	0	1	0	1	1	1	6
Sahin et al (2016)[15]	1	0	1	0	0	1	1	0	1	1	6
Ferber et al (2015)[32]	1	1	1	0	0	0	0	1	1	1	6
Ferber et al (2011)[37]	0	0	1	0	0	0	1	1	1	1	5
Willy et al (2011)[39]	1	0	1	0	0	0	1	0	1	1	5
Khayambashi et al (2014)[8]	0	0	1	0	0	0	1	0	1	1	4
Studies excluded from the meta-analysis due to lack or specific comparative groups											
Steinberg et al (2019)[41]	1	1	1	0	0	1	1	1	1	1	8
Rabelo et al (2018)[30]	1	1	1	0	0	1	1	1	1	1	8
De Baldon et al (2014)[40]	1	1	1	0	0	0	1	1	1	1	7
Chevidikunnan et al (2016)[28]	1	1	1	0	0	0	1	1	1	1	7
Van Linschoten et al (2009)[29]	1	1	1	0	0	0	1	1	1	1	7
Khayambashi et al (2012)[39]	1	0	1	0	0	0	1	0	1	1	5
Foroughi et al (2019)[42]	1	0	1	0	0	0	0	0	1	1	4
Avraham et al (2007)[45]	1	0	0	0	0	1	0	0	1	0	3

(0.9)). Only five studies assessed the intensity, set as the percentage of one-repetition maximum ranging from 60% - 75%. Four studies reported breaks allowed between series (range: 30–180 seconds) and the breaks between blocks were only reported in two studies (60 and 120 seconds).

Effects of Exercise Programs on Pain Relief and Functional Improvement

Changes in pain relief according to changes in the VAS were reported in sixteen studies, of which thirteen were rated as being of "good" quality [10,15,17,18,28–36] and three as being of "fair" quality.[8,37,38] Although the meta-analysis was limited, as there were insufficient studies comparing hip-only or knee-only exercise with Control groups for pain relief, eleven studies examining Hip or Hip&Knee exercise programs compared with a knee-only exercise were eventually included in this meta-analysis (Figure 2).

A statistically significant decrease in the perceived pain according to the VAS across studies was found when comparing Hip or Hip&Knee exercise programs and Knee-only exercise programs (MD = −0.94 (−1.84, −0.04); $p = 0.04$; $I^2 = 97\%$). Hip&Knee exercise programs (MD = −1.71 (−3.11, −0.30); $p = 0.02$; $I^2 = 96\%$) seemed to be superior to Hip exercise programs (MD = −0.26 (−0.92, −0.41); $p = 0.45$; $I^2 = 87\%$) for pain relief. However, the difference between exercise programs for VAS was not statistically significant ($p = 0.07$). Analysis of sensitivity demonstrated that the difference was statistically significant when the most effective Hip study was removed ($p = 0.02$). Similarly, when comparing the same intervention groups, a statistically significant improvement in the function assessed by AKPS or LEFS was found (Figure 3). Two included studies assessed functional changes with LEFS,[10,31] while eight studies used AKPS.[8,15,17,18,32–35] Two additional studies used the WOMAC to assess functional changes, but were not included in the meta-analysis due to substantial discrepancy between intervention groups.[8,39] Both Hip only (SMD = 0.48 (0.08, 0.88); $p = 0.02$; $I^2 = 71\%$) or Hip&Knee exercise programs (SMD = 1.28 (0.45, 2.12); $p = 0.003$; $I^2 = 84\%$) proved to be superior to Knee

Table 2 Inclusion and Exclusion Criteria, Outcome Measures, Compliance Rate and Main Findings of Included Studies

Author	Inclusion Criteria	Exclusion Criteria	Outcome Measures	Compliance	Findings
Hott et al (2019)[17]	16–40y; ≥3 month history of PFP ≥3 on VAS, reproduced by at least 2 activities (stair ascent/descent, hopping, running, prolonged sitting, squatting, kneeling) and present on at least 1 clinical test (compression of the patella, palpation of the patellar facets)	Clinical, radiographic, or MRI findings of meniscal, ligament, cartilage injury, osteoarthritis, epiphysitis, knee joint effusion, recurrent patellar subluxation or dislocation; pain from hip or back hindering the ability to perform exercises; surgery to the knee; nonsteroidal anti-inflammatory drug or cortisone use; trauma to the knee; physiotherapy or other similar exercises for PFP syndrome within the previous 3 months	AKPS, VAS, MVIC	92%	No difference in short-term effectiveness in combining patient education with knee-focused exer- cise, hip-focused exercise, or free training for patients with PFP.
Saad et al (2018)[18]	Insidious onset of symptoms; retropatellar or peripatellar pain with at least 2 of the following activities (ascending/ descending stairs, running, kneeling, squatting, prolonged sitting or jumping)	History of knee surgery; history of back, hip, or ankle joint injury or pain; patellar instability; lesion or pain during palpation or test of any structure of knee; neurological involvement that would affect gait	AKPS, VAS, MVIC	NR	All treatment groups showed significant improvements on pain and AKPS score after intervention with no statistically significant differences between groups except when compared to the control group. Only hip and quadriceps groups demonstrated improvements in muscle strength and knee valgus angle during the step activities.
Fukuda et al (2012)[10]	PFP for ≥3 months and increasing pain in 2 or more activities that commonly provoke PFP: ascending and descending stairs, squatting, kneeling, jumping, long sitting, isometric knee extension contraction at 60° of knee flexion, pain on palpation of the medial and/or lateral facet of the patella; sedentary women; defined as not having practiced physical activity any day of the week for ≥6 months	Neurological disorder; injury to the lumbosacral region, hip, or ankle; rheumatoid arthritis, a heart condition, or previous surgery involving the lower extremities; pregnancy; use of corticosteroids or anti-inflammatories; patellar instability, patellofemoral dysplasia, meniscal or ligament tears, osteoarthritis, or tendinopathies	AKPS, VAS, LEFS	90%	Knee-stretching and -strength- ening exercises supplemented by hip posterolater- al musculature–strengthening exercises were more effective than knee exercises alone in improving long-term function and reducing pain in sedentary women with PFP.
Hott et al (2020)[33]	16–40y; ≥3 months history of PFP; pain score for worst pain intensity during previous week of ≥3 on VAS, reproduced by at least two of the following activities: stair ascent or descent; hopping, running, prolonged sitting, squatting or kneeling and present on at least one of the following clinical tests:compression of the patella or palpation of the patellar facets	Clinical, radiographic, or MRI findings of meniscal, ligament, cartilage injury, osteoarthritis, epiphysitis, knee joint effusion, recurrent patellar subluxation or dislocation; pain from hip or back hindering the ability to perform exercises; surgery to the knee; nonsteroidal anti-inflammatory drug or cortisone use; trauma to the knee; physiotherapy or other similar exercises for PFP syndrome within the previous 3 months	AKPS, VAS, MVIC	90%	After one year, there was no difference in effectiveness of knee exercise, hip exercise or free physical activity, when combined with patient education in PFP.
Ismail et al (2013)[35]	Anterior or retropatellar knee pain from at least 2 of the following activities regardless of the level of pain intensity prolonged sitting, stair climbing, squatting, running, kneeling and hopping/jumping; insidious onset of symptoms unrelated to a traumatic incident and persistent for ≥6w; had not previously received physical therapy	Meniscal or other intra articular pathologic conditions; cruciate or collateral ligament involvement; patellar subluxation or dislocation; previous surgery in the knee and hip joints; knee and hip joints osteoarthritis; any conditions affects muscle strength like diabetes mellitus or rheumatoid arthritis	AKPS, VAS, MVIC	NR	Six weeks closed kinetic chain program focusing on knee and hip strengthening has similar effect in improving hip muscles torque in patients with PFP as a closed kinetic chain exercises with additional hip strengthening exercises. However, adding isolated hip strengthening exercises has the advantage of more pain relief.

(*Continued*)

Table 2 (Continued).

Author	Inclusion Criteria	Exclusion Criteria	Outcome Measures	Compliance	Findings
Nakagawa et al (2008)[36]	Anterior or retropatellar knee pain during at least three of the following activities: ascending/descending stairs, squatting, running, kneeling, hopping/jumping and prolonged sitting; the insidious onset of these symptoms being unrelated to a traumatic incident and persistent for ≥4w; presence of pain on palpation of the patellar facets, on stepping down from a 25-cm step, or during a double-legged squat	Meniscal or other intra-articular pathologic conditions; cruciate or collateral ligament involvement; tenderness over the patellar tendon, iliotibial band, or pes anserinus tendons; patellar apprehension; Osgood–Schlatter or Sinding– Larsen–Johansson syndromes; hip or lumbar referred pain; a history of patellar dislocation; evidence of knee joint effusion; or previous surgery on the patellofemoral joint	VAS, MVIC	NR	Supplementation of strengthening of hip abductor and lateral rotator muscles in a strengthening quadriceps exercise programme provided additional benefits with respect to the perceived pain symptoms during functional activities in patients with PFP after 6 weeks of treatment.
Dolak et al (2011)[31]	Anterior or retropatellar knee pain during at least 2 of the activities of stair climbing, hopping, running, squatting, kneeling, and prolonged sitting; an insidious onset of symptoms not related to trauma; pain with compression of the patella; pain on palpation of patellar facets	Symptoms present for <1 month; cartilage injury or ligamentous tear; history of knee surgery within the last year; self-reported history of patella dislocations or subluxations; any other concurrent significant injury affecting the lower-extremity	VAS, LEFS, MVIC	80%	Both rehabilitation approaches improved function and reduced pain. For patients with PFP, initial hip strengthening may allow an earlier dissipation of pain than exercises focused on the quadriceps.
Fukuda et al (2010)[34]	Females aged 20–40y; history of anterior knee pain for ≥3 months and reported pain in 2 or more daily activities: ascending and descending stairs, squatting, kneeling, jumping, long sitting, isometric knee extension contraction at 60° of knee flexion; pain on palpation of the medial and/or lateral facet of the patella	Pregnancy; neurological disorders, hip or ankle injuries, low back or sacroiliac joint pain, rheumatoid arthritis; heart condition that precluded performing the exercises; previous surgery involving the lower extremities; patellar instability; patellofemoral dysplasia; meniscal or ligament tears; osteo- arthritis; tendinopathies; epiphysitis	AKPS, VAS, MVIC	NR	Rehabilitation programs focusing on knee strengthening exercises and knee strengthening exercises supplemented by hip strengthening exercises were both effective in improving function and reducing pain in sedentary women with PFP.
Sahin et al (2016)[15]	Sedentary females aged 20–45y; patients with a full ROM of the knee joints; presence of anterior or retropatellar knee pain during at least 3 of the following activities: ascending/descending stairs, squatting, hopping/running, prolonged sitting; insidious onset of symptoms unrelated to a traumatic incident and persistence of symptoms for at least 4 weeks; a score of ≥3 on the VAS; presence of pain on palpation of the patellar facets; presence of pain on stepping down from a 25-cm step or double-legged squat	Current significant injury affecting lower limb joints; surgery of the knee joint; signs or symptoms or MRI findings of intraarticular pathologic conditions such as effusion, meniscal, cruciate or collateral ligament involvement; tenderness of the patellar tendon or iliotibial band or pes anserinus tendon; patellar subluxation or dislocation; signs of patellar apprehension; referred pain with hip pain, or back pain; acute strain or sprain; current use of nonsteroid antiinflammatory drugs or corticosteroids	AKPS, VAS, MVIC	91%	The improvements of the patients in the hip-and-knee exercise group were better than in patients of the knee-only exercise group in terms of scores of pain relief and functional gain after 12 weeks.

Ferber et al (2015)[32]	≥3 on the VAS scale; insidious onset of symptoms unrelated to trauma; pain during at least 3 of the following activities: ascending/descending stairs, squatting, running, kneeling, jumping, and prolonged sitting; pain with palpation of the patellar facets; recreationally active (≥30 min/day, 3–4 days a week)	Meniscal or other intra-articular injury; cruciate or collateral ligament laxity or tenderness; patellar tendon, iliotibial band, or pes anserine tenderness; positive patellar-apprehension sign; Osgood-Schlatter or Sinding-Larsen-Johansson syndrome; evidence of effusion; hip or lumbar referred pain; history of recurrent patellar subluxation or dislocation; surgery to the knee; history of head injury or vestibular disorder within the last 6 months; pregnancy	AKPS, VAS, MVIC	81%	Although outcomes were similar, the HIP protocol resulted in earlier resolution of pain and greater overall gains in strength compared with the KNEE protocol.
Ferber et al (2011)[37]	Anterior or retropatellar knee pain, with a severity of ≥3 on VAS, during at least 2 of the following activities: ascending and descending stairs, hopping and running, squatting or kneeling, prolonged sitting; insidious onset of symptoms unrelated to trauma; pain with compression of the patella; pain on palpation of patellar facets	Unilateral symptoms present for >2 months; self-reported clinical evidence of other knee conditions; history of knee surgery; self-reported history of patellar dislocations or subluxations; current significant injury affecting other lower extremity joints	VAS, MVIC	NR	A 3-week hip-abductor muscle-strengthening protocol was effective in increasing muscle strength and decreasing pain and stride-to-stride knee-joint variability in individuals with PFP.
Willy et al (2011)[39]	Female runners aged 18–35y; running at least 10 km per week; excessive peak hip adduction during running	Free from any musculoskeletal sugrery that would affect their running or squatting mechanics	MVIC	100%	A training program that included hip strengthening and movement training specific to single-leg squatting did not alter running mechanics but did improve single-leg squat mechanics.
Khayambashi et al (2014)[8]	Peripatellar and/or retropatellar pain; reproduction of pain with activities commonly associated with this condition (eg, stair decent, squatting, kneeling, prolonged sitting)	Ligamentous laxity; meniscal injury; pes anserine bursitis; iliotibial band syndrome; patella tendinitis; history of patella dislocation; patella fracture; knee surgery; previous physical therapy; symptoms that had been present for <6 months	VAS, WOMAC	93%	Although both intervention programs resulted in decreased pain and improved function in persons with PFP, outcomes in the posterolateral hip exercise group were superior to the quadriceps exercise group.
Steinberg et al (2019)[41]	Full-time student in one of the dancing programs, diagnosed by one of two orthopedic surgeons as having PFP	Previous knee surgery	VAS, MVIC	NR	Both isometric exercises and somatosensory training were effective for decreasing clinical symptoms and improving some functional abilities in young dancers with PFP.
Rabelo et al (2018)[30]	Females aged 18–30y; PFP for ≥3 months related to at least 2 of the following activities: prologned sitting, climbing or descending stairs, squatting, kneeling or jumping; pain on palpation	History of surgery in the lower limbs; recurrent patellar instability; disorders associated with meniscal and/or ligamentous injuries; cardiac or locomotor disorders that could affect the assessment and treatment	AKPS, VAS, MVIC	NR	Movement control training was no more effective than the isolated strengthening protocol, in terms of pain, function, muscle strength, or kinematics.
De Baldon et al (2014)[40]	≥3 on the VAS scale; anterior or retropatellar knee pain during at least 3 of the following activities: ascending/descending stairs, squatting, running, kneeling, jumping, and prolonged sitting; an insidious onset of symptoms unrelated to trauma	Intra-articular pathology; involvement of cruciate or collateral ligaments; patellar instability; Osgood-Schlatter or Sinding- Larsen-Johansson syndrome; hip pain; knee joint effusion; surgery in the lower limb; pain on palpation of the patellar tendon, iliotibial band, or pes anserinus tendons	VAS, LEFS, MVIC	NR	An intervention program consisting of hip muscle strengthening and lower-limb and trunk movement control exercises was more beneficial in improving pain, physical function, kinematics, and muscle strength compared to a program of quadriceps-strengthening exercises alone.

(*Continued*)

Table 2 (Continued).

Author	Inclusion Criteria	Exclusion Criteria	Outcome Measures	Compliance	Findings
Chevidikunnan et al (2016)[28]	Females aged 16–40y; PFP for ≥4 weeks that was aggravated by at least 2 of the following activities: jumping, running, prolonged sitting, stair climbing, kneeling, and squatting; positive patellar grinding test; must be active for at least 30 min/day	Cruciate, meniscal, collateral ligament injuries or tenderness; intra-articular injury; tenderness over the illiotibial band, patellar tendon, or pes anserine tendons; Sinding-Larsen-Johanssen syndromes or Osgood-Schlatter disease; evidence of joint effusion, referred pain from the hip or lumbar region, known case of articular cartilage damage	VAS	NR	Adding a core muscle-strengthening program to the conventional physical therapy management improves pain and dynamic balance in female patients with PFP.
Van Linschoten et al (2009)[29]	Pain during stair ascending or descending, squatting, running, cycling or when sitting with knees flexed for a prolonged period of time; grinding of the patella; positive clinical patellar test (Clark's test)	Knee osteoarthritis; patellar tendinopathy; Osgood-Schlatter disease; other defined pathological conditions of the knee; previous knee injuries or surgery	VAS	NR	Supervised exercise therapy resulted in less pain and better function at short and long term follow-up compared with usual care in patients with PFP.
Khayambashi et al (2012)[39]	Peripatellar and/or retropatellar pain related to prolonged sitting, climbing or descending stairs, squatting, kneeling or jumping	Ligamentous laxity; meniscal injury; pes anserine bursitis; iliotibial band syndrome; patellar tenidinitis; history of patellar dislocation or fracture; knee surgery	VAS, WOMAC, MVIC	NR	Isolated hip strengthening was effective in improving pain and health status in females with PFP compared with a control group with no intervention.
Foroughi et al (2019)[42]	Females aged 18–30y; PFP for ≥3 months related to prolonged sitting, climbing or descending stairs, squatting, kneeling or jumping; pain on palpation, active ≥ 30 minutes/day	History of knee pathologies; history of patellar subluxation or dislocation; lumbopelvic-hip complex pathology; spinal or lower extremity fracture; knee surgery within the previous year; metabolic or neuromuscular disease	VAS, AKPS	NR	Greater pain relief and functional improvement has been shown in the Hip&Knee&Core group compared to the Hip&Knee group.
Avraham et al (2007)[45]	Positive PF gliding test; negative McMurry test; full ROM; pain related to prolonged sitting, climbing or descending stairs	History of knee trauma; degenerative changes in the PFJ	VAS	60%	Hip&Knee, Hip only and Knee only exercise showed similar efficiency, with stronger significance to the groups who combined hip strengthening and stretching exercises.

Table 3 Exercise Programs Description

Author	N	Gender	Age	Type	Duration (Weeks)	Frequency (x Week)	Number of Exercises	Number of Sets	Repetitions	Progression
Studies included in the meta-analysis										
Hott et al (2019)[17]	Hip (n=39)	Both	16–40	Strength	6	3	3	3	10–20	Yes Yes
	Knee (n=37)	Both	16–40	Strength	6	3	3	3	10–20	
	Control (n=37)	Both	16–40	/	/	/	/	/	/	/
Saad et al (2018)[18]	Hip (n=10)	F	18–28	Strength	8	2	5	3	10	Yes
	Knee (n=10)	F	18–28	Strength	8	2	5	3	10	Yes
	Stretching (n=10)	F	18-28	Stretching	8	2	7	3	1	Yes
	Control (n=10)	F	18-28	/	/	/	/	/	/	/
Fukuda et al (2012)[10]	Hip&Knee (n=28)	F	20–40	Strength	4	3	10	3	10	Yes
	Knee (n=26)	F	20–40	Strength	4	3	6	3	10	Yes
Hott et al (2020)[33]	Hip (n=39)	Both	16–40	Strength	6	3	3	3	10–20	Yes
	Knee (n=37)	Both	16–40	Strength	6	3	3	3	10–20	Yes
	Control (n=37)	Both	16-40	/	/	/	/	/	/	/
Ismail et al (2013)[35]	Hip&Knee (n=16)	Both	18–30	Strength	6	3	6	1–2	10	Yes
	Knee (n=16)	Both	18–30	Strength	6	3	4	1	10	Yes
Nakagawa et al (2008)[36]	Hip&Knee (n=7)	Both	17–40	Strength	6	5	4	2	15	No
	Knee (n=7)	Both	17-40	Strength	6	5	3	3	10	No
Dolak et al (2011)[31]	Hip (n=17)	F	16–35	Strength	8	3	3–4	3	10	Yes
	Knee (n=16)	F	16-35	Strength	8	3	3–4	3	10	Yes
Fukuda et al (2010)[34]	Hip&Knee (n=21)	F	20–40	Strength	4	3	9	3	10	Yes
	Knee (20)	F	20-40	Strength	4	3	5	3	10	Yes
	Control (n=24)	F	20-40	/	/	/	/	/	/	/

(*Continued*)

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Table 3 (Continued).

Author	N	Gender	Age	Type	Duration (Weeks)	Frequency (x Week)	Number of Exercises	Number of Sets	Repetitions	Progression
Sahin et al (2016)[15]	Hip&Knee (n=25)	F	20–45	Strength	6	5	7	2	5–30	Yes
	Knee (n=25)	F	20-45	Strength	6	5	5	2	5-30	Yes
Ferber et al (2015)[32]	Hip (n=111)	Both	NR	Strength	6	3	3-4	3	10–15	Yes
	Knee (n=88)	Both	NR	Strength	6	3	3–5	3	10-15	Yes
Ferber et al (2011)[37]	Hip (n=15)	Both	NR	Strength	3	7	2	3	10	No
	Control (n=10)	Both	NR	/	/	/	/	/	/	/
Willy et al (2011)[39]	Hip (n=10)	F	18–35	Strength	6	3	2	2	10	Yes
	Control (n=10)	F	18-35	/	/	/	/	/	/	
Khayambashi et al (2014)[8]	Hip (n=18)	Both	NR	Strength	8	3	2	3	20–25	Yes
	Knee (n=18)	Both	NR	Strength	8	3	2	3	20–25	Yes
Studies excluded from the meta-analysis due to lack or specific comparative groups										
Steinberg et al (2019)[41]	Hip&Knee (n=18)	F	12–15	Strength	12	3	7	3	10-20	Yes
	SST (n=18)	F	12–15	Balance	12	3	5	1	15	Yes
	Stretching (n=28)	F	12-15	Stretching	12	3	5	1	1	No
Rabelo et al (2018)[30]	Hip&Knee&SST (n=17)	F	18–30	Strength&SST	4	3	7	3	10-20	Yes
	Hip&KneeKnee (n=17)	F	18–30	Strength	4	3	7	3	10	Yes
De Baldon et al (2014)[40]	FST (n=15)	F	18-30	Strength&FST	8	3	8–10	2–5	12–20	Yes
	Knee (n=16)	F	18-30	Strength	8	3	6-8	2-3	12-20	Yes
Chevidikunnan et al (2016)[28]	Hip&Knee&Core (n=10)	F	16-40	Strength	4	3	4	1	20–23	Yes
	Hip&Knee (n=10)	F	16-40	Strength	4	3	3	1	20-23	Yes

Van Linschoten et al (2009)[29]	Hip&Knee (n=65)	Both	14–40	Strength	6	5	NR	NR	NR	Yes
	Control (n=66)	Both	14-40	/	/	/	/	/	/	/
Khayambashi et al (2012)[39]	Hip (n=14)	F	NR	Strength	8	3	2	3	20-25	Yes
	Control (n=14)	F	NR	/	/	/	/	/	/	
Foroughi et al (2019)[42]	Hip&Knee&Core (n=17)	F	18-30	Strength	4	3	7	3-5	10	Yes
	Hip&Knee (n=16)	F	18-30	Strength	4	3	6	3-5	10	Yes
Avraham et al (2007)[45]	Hip&Knee (n=10)	Both	NR	Endurance	3	2	5	1	1	No
	Hip (n=10)	Both	NR	Endurance	3	2	3	1	1	No
	Knee (n=10)	Both	NR	Endurance	3	2	2	1	1	No

Abbreviations: Hip, hip focused exercise program; Knee, knee focused exercise program; Hip&Knee, hip and knee focused exercise program, SST, somatosensory training, FST, functional stabilization training, NR, not reported.

exercise programs in terms of functional improvements (SMD = 0.79 (0.35, 1.24); $p < 0.05$; $I^2 = 84\%$). Although the Hip&Knee exercise appeared superior to the Hip-only exercise, the difference did not reach statistical significance (p = 0.09). Considering the high heterogeneity among studies, the elimination of many studies (3 in hip subgroup and 1 in Hip&Knee subgroup) resulted in a change to a statistically significant difference (p = 0.-02–0.04). When comparing hip-only and knee-only exercise programs with Control groups without interventions, seven studies assessing functional changes with AKPS were found [17,18,33,34] (Figure 4). Both exercise programs showed significant functional improvements compared to the Control groups (MD = 2.97 (0.09, 5.85); p = 0.04; $I^2 = 92\%$), although no significant difference between intervention groups was found (p = 0.97). Sensitivity analyses did not reveal any difference to statistical significance.

Effects of Exercise Programs on Muscle Strength

Hip abduction and external rotation strength were doubtlessly the most commonly reported outcomes, assessed in fourteen studies,[15,17,18,30–33,35–41] of which eleven were included in the meta-analysis.

Strength of the hip abduction was reported in eleven studies comparing hip-only or knee-only exercise programs and Control groups with no intervention.[15,17,18,31–33,35–39] A significant increase in muscle strength was found across all intervention groups (SMD = 1.27 (0.86, 1.67); $p < 0.05$; $I^2 = 67\%$). Hip exercise programs appeared to be superior (SMD = 1.50 (0.85, 2.15); $p < 0.05$; $I^2 = 77\%$) to Knee exercise programs (SMD = 1.07 (0.68, 1.47); $p < 0.05$; $I^2 = 27\%$), although surprisingly, regardless of the overall improvement, a significant difference in the effects between Hip exercise and Knee exercise was not found (p = 0.27). Sensitivity analyses did not reveal any difference to statistical significance. Furthermore, no statistically significant increases in hip abduction strength across studies were found comparing Hip only and Hip&Knee exercise programs with Knee only exercise programs (SMD = 0.29 (−0.17, 0.75); p = 0.21; $I^2 = 81\%$). Hip&Knee exercise programs (SMD = 0.76 (0.35, 1.18); $p < 0.003$; $I^2 = 0\%$) seemed to be superior (p = 0.05 for subgroup difference) to Hip only exercise programs (SMD = 0.08 (−0.47, 0.63); p =0.77; $I^2 = 83\%$) (Supplementary Figure 1). The results were very heterogeneous among studies, and elimination

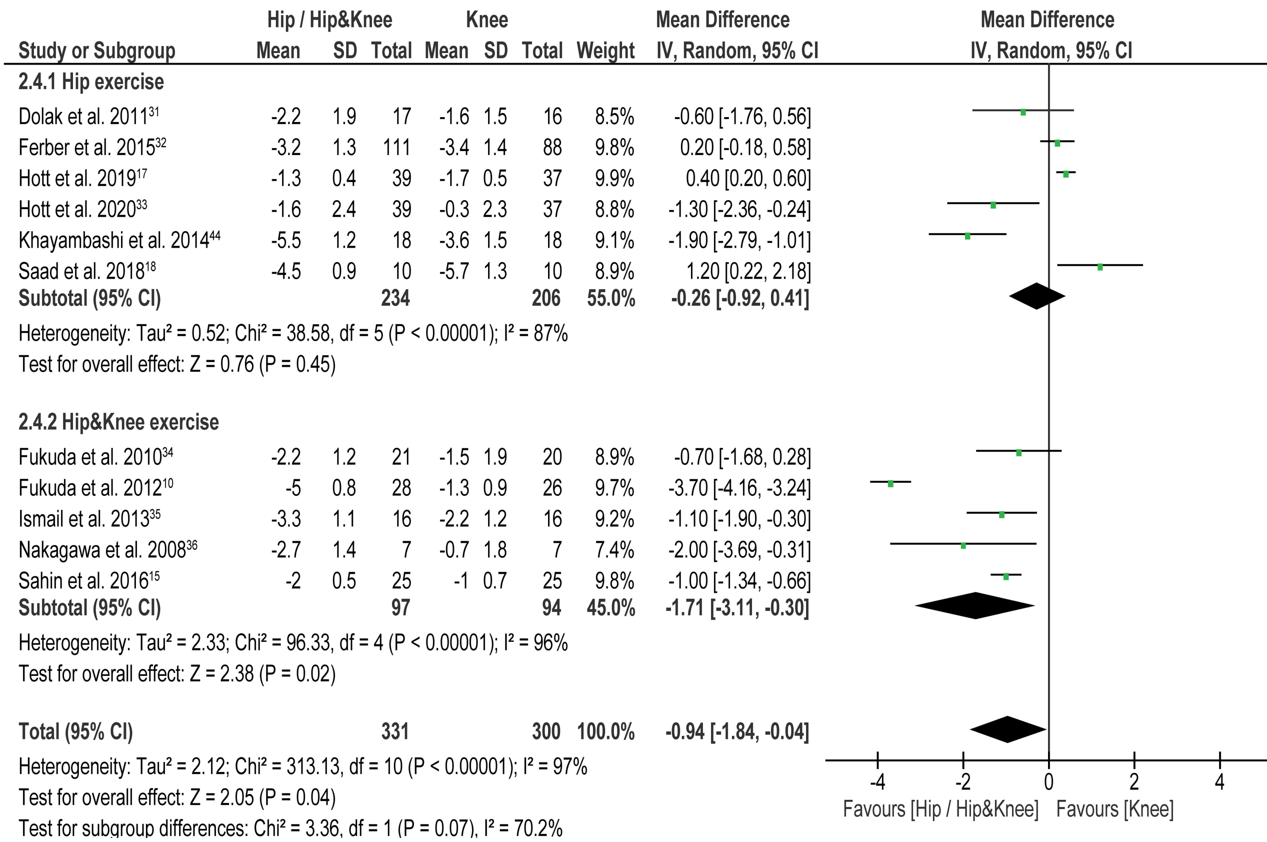

Figure 2 Hip only or Hip&Knee exercise programs compared with Knee only exercise programs for pain relief (VAS).

of many studies (3 in hip subgroup and 2 in Hip&Knee subgroup) resulted in a change to a statistically significant difference (p = 0.21–0.34).

Hip external rotation was reported in ten studies.[15,17,18,31–33,35,36,38,39] Compared to Control groups with no intervention Hip-only exercise and knee-only exercise showed a statistically significant increase in hip external rotation strength (SMD = 0.79 (0.58, 1.22); $p < 0.05$; $I^2 = 41\%$). Both Hip only exercise (SMD = 0.77 (0.32, 1.22); $p < 0.05$; $I^2 = 60\%$) and Knee only exercise (SMD = 0.90 (0.58, 1.22); $p < 0.05$; $I^2 = 0\%$) proved to be superior to Controls, although without significant differences between the intervention groups (p = 0.64) (Supplementary Figure 2). Sensitivity analyses did not reveal any difference to statistical significance. A higher hip external rotation strength was found in Hip only exercise and Hip&Knee exercise programs compared to Knee only exercise program, although this change did not reach statistical significance (SMD = 0.35 (−0.06, 0.77); $p < 0.09$; $I^2 = 77\%$). Additionally, there were no differences between Hip only (SMD = 0.19 (−0.28, 0.66); $p < 0.43$; $I^2 = 77\%$) and Hip&Knee exercise programs (SMD = 0.70 (0.13, 1.26); $p < 0.02$; $I^2 = 40\%$) (p = 0.17 for subgroup differences). Sensitivity analyses did not reveal any difference to statistical significance.

Discussion

The main aim of this systematic review and meta-analysis was to evaluate the effects of exercise programs for trunk, hip or knee muscles on pain relief, functional improvements and muscle strength in patients with PFP. The meta-analysis included studies with at least one exercise program and a control group with or without exercise interventions. Following the search strategy and according to the inclusion criteria, we included twenty-one studies in the systematic review. After further assessment, we included thirteen studies in the meta-analysis. Eight studies were not included in the meta-analysis due an absence of comparative groups or specific comparative groups. Regardless, they were included in the systematic review. The search strategy did not result in studies specifically investigating trunk muscle exercise programs in patients with PFP, although two studies investigated the addition of trunk exercises on Hip&Knee exercise programs.[28,42] Previous reviews have

Study or Subgroup	Hip / Hip&Knee Mean	SD	Total	Knee Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
1.6.1 Hip exercise								
Dolak et al. 2011[31]	11	8	17	11	8.88	16	9.6%	0.00 [-0.68, 0.68]
Ferber et al. 2015[32]	12.6	7.6	111	12.1	7.2	88	11.9%	0.07 [-0.21, 0.35]
Hott et al. 2019[17]	8.8	2.4	39	7.3	3.3	37	11.0%	0.52 [0.06, 0.97]
Hott et al. 2020[33]	13.1	2.8	39	9.4	4.1	37	10.9%	1.05 [0.57, 1.53]
Khayambashi et al. 2014[44]	40.61	19.13	18	22.22	14.58	18	9.5%	1.06 [0.35, 1.76]
Saad et al. 2018[18]	14.4	3.9	10	13.2	5.8	10	8.3%	0.23 [-0.65, 1.11]
Subtotal (95% CI)			**234**			**206**	**61.3%**	**0.48 [0.08, 0.88]**
Heterogeneity: Tau² = 0.17; Chi² = 17.42, df = 5 (P = 0.004); I² = 71%								
Test for overall effect: Z = 2.36 (P = 0.02)								
1.6.2 Hip&Knee exercise								
Fukuda et al. 2010[34]	15	10.6	21	10.2	9.4	20	10.0%	0.47 [-0.15, 1.09]
Fukuda et al. 2012[10]	19.8	6.8	28	2.8	6.9	26	9.4%	2.45 [1.73, 3.16]
Ismail et al. 2013[35]	13.6	5.2	16	8.6	6.9	16	9.4%	0.80 [0.07, 1.52]
Sahin et al. 2016[15]	14	4	25	6.7	5.8	25	10.0%	1.44 [0.81, 2.07]
Subtotal (95% CI)			**90**			**87**	**38.7%**	**1.28 [0.45, 2.12]**
Heterogeneity: Tau² = 0.61; Chi² = 18.61, df = 3 (P = 0.0003); I² = 84%								
Test for overall effect: Z = 3.01 (P = 0.003)								
Total (95% CI)			**324**			**293**	**100.0%**	**0.79 [0.35, 1.24]**
Heterogeneity: Tau² = 0.41; Chi² = 55.47, df = 9 (P < 0.00001); I² = 84%								
Test for overall effect: Z = 3.53 (P = 0.0004)								
Test for subgroup differences: Chi² = 2.85, df = 1 (P = 0.09), I² = 65.0%								

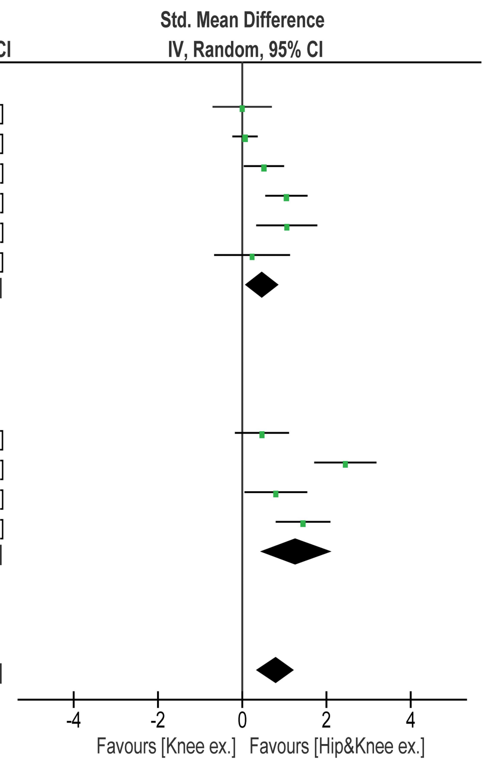

Figure 3 Hip only or Hip&Knee exercise programs compared with Knee only exercise programs for function (AKPS; LEFS).

Study or Subgroup	Hip / Knee ex. Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
1.5.1 Hip exercise								
Hott et al. 2019[17]	8.8	2.4	39	8.3	3.1	37	17.2%	0.50 [-0.75, 1.75]
Hott et al. 2020[33]	13.1	2.7	39	13.4	3.8	37	17.0%	-0.30 [-1.79, 1.19]
Saad et al. 2018[18]	14.4	3.9	10	1.1	7.1	10	11.5%	13.30 [8.28, 18.32]
Subtotal (95% CI)			**88**			**84**	**45.7%**	**3.33 [-0.69, 7.35]**
Heterogeneity: Tau² = 10.65; Chi² = 26.00, df = 2 (P < 0.00001); I² = 92%								
Test for overall effect: Z = 1.62 (P = 0.10)								
1.5.2 Knee exercise								
Fukuda et al. 2010[34]	10.2	9.4	20	0.7	10.3	23	10.2%	9.50 [3.61, 15.39]
Hott et al. 2019[17]	7.3	3.3	37	8.3	3.1	37	17.0%	-1.00 [-2.46, 0.46]
Hott et al. 2020[33]	9.4	4.1	37	13.4	3.8	37	16.6%	-4.00 [-5.80, -2.20]
Saad et al. 2018[18]	13.2	5.8	10	1.1	7.1	10	10.5%	12.10 [6.42, 17.78]
Subtotal (95% CI)			**104**			**107**	**54.3%**	**3.19 [-1.89, 8.27]**
Heterogeneity: Tau² = 22.73; Chi² = 43.07, df = 3 (P < 0.00001); I² = 93%								
Test for overall effect: Z = 1.23 (P = 0.22)								
Total (95% CI)			**192**			**191**	**100.0%**	**2.97 [0.09, 5.85]**
Heterogeneity: Tau² = 12.13; Chi² = 75.66, df = 6 (P < 0.00001); I² = 92%								
Test for overall effect: Z = 2.02 (P = 0.04)								
Test for subgroup differences: Chi² = 0.00, df = 1 (P = 0.97), I² = 0%								

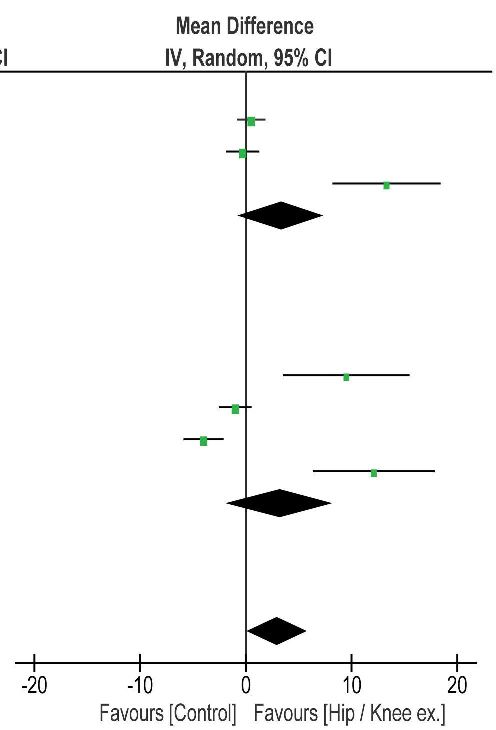

Figure 4 Hip only or Knee only exercise programs compared with controls for function (AKPS).

addressed the question of the effectiveness of exercise programs that focus on muscle groups proximal to the knee in terms of pain, function or strength in patients with PFP.[21,43] However, these reviews either included passive interventions or showed a high heterogeneity in the protocol type, used methods and outcome measures.

The main findings of this systematic review with meta-analysis are: 1) Hip only or Hip&Knee exercise programs contribute to pain relief more than Knee only exercise programs, 2) Hip only or Hip&Knee exercise programs improve function more than Knee only exercise program, 3) there is no statistically significant difference between Hip&Knee and Hip only exercise programs in any of the outcome measures, 4) our search strategy did not discover studies investigating foot and ankle muscle exercise programs without additional taping or bracing on patients with PFP. Overall, hip exercise with or without accompanying knee exercise seemed to be the most effective approach for pain relief, function gains and hip muscle strength.[8,10,15,17,18,31–35,44] The small number of comparable studies are an important limitation of this review, particularly regarding the exercise program design and strength outcome measures. Comparisons between different exercise programs were limited and, for some outcome measures, not possible due to high heterogeneity in terms of the studied muscle groups and different intervention groups.

Positive effects of hip exercise programs in patients with PFP have been reported numerous times.[8,17,18,31–33,37,39,45] In the present study, we included randomized controlled trials evaluating exercise programs only with at least one intervention and control group with or without intervention. Hip-only exercise programs seemed to be superior to knee-only exercise programs in terms of pain relief[8,31,33] and functional improvement.[8,17,18,32,33] Our review confirmed that hip exercise programs lead to greater pain relief and functional improvement than knee exercise programs.[18,31] In a single study, a decrease in pain levels did not reach statistical significance. However, although both Knee-only and Hip-only exercise programs proved to be equally effective in relieving pain, the latter programs appear to result in faster pain relief and a higher overall increase in muscle strength.[32] In addition, studies support the use of hip muscle strengthening in the early stages of PFP rehabilitation when excessive knee involvement provokes further pain.[46,47] Overall, the use of hip-only exercise programs over knee-only exercise programs may be recommended in early rehabilitation, but the importance of knee muscle strengthening on PFP cannot be completely eliminated.

Evidence suggests that a combined exercise approach results in greater pain reduction when compared with knee-only exercise programs.[10,15,34,35,44] It is suggested that superior pain relief in a combined Hip&Knee exercise program is due to lower PFJ loading in comparison to the Knee-only exercise programs. A recent systematic review with meta-analysis confirms these results and recommends the inclusion of exercise programs focusing on muscle groups proximal to the knee in PFP to achieve the best possible outcome.[21] However, although Hip&Knee exercise programs showed greater pain relief, functional improvements and hip muscle strength increase compared to Knee exercise programs, when comparing pooled data from Hip&Knee and Hip only exercise programs, the combined approach tended to be superior, but this change was not statistically significant in any of the outcome measures. Our results are consistent with the conclusions of a study conducted by Avraham et al,[45] where pain and function improvements did not differ significantly among Hip&Knee and Hip only exercise groups. It should be noted that the addition of knee strengthening exercises was only evaluated in the above-mentioned study, while the majority of studies focused on the added value of hip strengthening exercises.[10,15,34,35,44] Our conclusions are therefore based on pooled data from included studies and further research is needed to compare combined hip and knee with hip-only exercise programs. An important aspect in interpreting these results is that most exercises targeting the hip muscles also indirectly affect the knee muscles. A similar situation arises when focusing on the knee without simultaneously targeting the hip muscles. However, when emphasising the strength of the quadriceps muscle with widely used exercises such as single-leg rise, it is easier to eliminate the influence of the postero-lateral hip muscles.

Clinical Implications

Caution is needed in interpreting the results of our study. Hip&Knee exercise programs appear to reduce pain and improve function more than Knee-only exercise programs and may be considered as a rehabilitation approach in patients with PFP. However, the difference between the subgroups in most outcome measures suggests that Hip&Knee exercise programs are not more effective than Hip-only exercise programs. Thus, our findings suggest that a combined Hip&Knee or Hip only exercise program could be equally successful among patients with PFP and incorporated the rehabilitation process based on current symptoms, without affecting the final outcome. Considering that pain relief and functional improvements are often the primary goals of patients' rehabilitation, clinicians should consider prescribing a mixed hip and knee exercise program when possible, in order to decrease the stress on the PFJ and provide and earlier alleviation of pain.

Limitations

There are several limitations to our study. It is difficult to provide clear clinical recommendations, as most studies showed a high variability in terms of program duration, volume (number of repetitions, sets or exercises), session duration or type of protocol. Further research is therefore needed to limit the high heterogeneity of exercise program duration and address the role of the duration itself. In this study, we have tried to limit our search to the most commonly used exercise programs in patients with PFP. This was used to intentionally summarize the results of these rehabilitation approaches. PEDro scale was used for the methodological assessment of study quality. Notably, none of the studies included in our review blinded the therapist or the subject on their group allocation, while only 43% of the studies blinded the investigator to the intervention. These results, consistent with previous reviews,[21] underline the need for a more consistent subject, therapist and assessor blinding to the group allocation. In addition, a limited number of studies with comparable intervention groups were found that examined knee extension strength, limiting the meta-analysis of the effects of exercise programs on the quadriceps muscle. Another limitation of this systematic review with meta-analysis lays in the inclusion of studies evaluating exclusively exercise rehabilitation. While this was done to compile exercise programs only, we are aware that other therapy methods such as bracing or taping may be effective in the management of PFP.

Conclusions

This systematic review with meta-analysis examined the effects of different exercise programs on pain relief, functional performance and hip muscle strength in patients with PFP. The results show that Hip&Knee and Hip only exercise programs are most effective in decreasing pain levels and improving functional performance, along with increasing hip abduction and external rotation strength. No subgroup difference was found between these two rehabilitation approaches for any of the outcome measures, although both showed superior compared to Knee-only exercise programs. To improve clinical applicability, further studies are needed to clearly define the critical components of the exercise program design and to investigate its effects in the long term. Regardless, hip muscle exercise programs may be successfully integrated into everyday clinical practice for the management of PFP.

Disclosure

The authors report no conflicts of interest in this work.

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