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Hip and Knee Strengthening Is More Effective Than Knee Strengthening Alone for Reducing Pain and Improving Activity in Individuals With Patellofemoral Pain: A Systematic Review With Meta-analysis

STUDY DESIGN: Systematic review with meta-analysis.

BACKGROUND: The addition of hip strengthening to knee strengthening for persons with patellofemoral pain has the potential to optimize treatment effects. There is a need to systematically review and pool the current evidence in this area.

OBJECTIVE: To examine the efficacy of hip strengthening, associated or not with knee strengthening, to increase strength, reduce pain, and improve activity in individuals with patellofemoral pain.

METHODS: A systematic review of randomized and/or controlled trials was performed. Participants in the reviewed studies were individuals with patellofemoral pain, and the experimental intervention was hip and knee strengthening. Outcome data related to muscle strength, pain, and activity were extracted from the eligible trials and combined in a meta-analysis.

RESULTS: The review included 14 trials involving 673 participants. Random-effects meta-analyses revealed that hip and knee strengthening decreased pain (mean difference, –3.3; 95% confidence interval [CI]: –5.6, –1.1) and improved activity (standardized mean difference, 1.4; 95% CI: 0.03, 2.8) compared to no training/placebo. In addition, hip and knee strengthening was superior to knee strengthening alone for decreasing pain (mean difference, –1.5; 95% CI: –2.3, –0.8) and improving activity (standardized mean difference, 0.7; 95% CI: 0.2, 1.3). Results were maintained beyond the intervention period. Meta-analyses showed no significant changes in strength for any of the interventions.

CONCLUSION: Hip and knee strengthening is effective and superior to knee strengthening alone for decreasing pain and improving activity in persons with patellofemoral pain; however, these outcomes were achieved without a concurrent change in strength.

LEVEL OF EVIDENCE: Therapy, level 1a–.
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Patellofemoral pain is a chronic condition characterized by retropatellar and/or peripatellar pain that worsens with squatting, sitting, climbing stairs, and running.[44] Although the annual incidence and true prevalence are still unknown, it has been described as one of the most common musculoskeletal conditions presenting to general practice and sports medicine clinics.[45,48] The pain and disability resulting from patellofemoral pain not only limit short-term performance in daily and physical activities, but also have the potential to interfere with long-term social participation, as 90% of patients report pain lasting up to 4 years after the onset of symptoms and 25% report significant symptoms lasting up to 20 years.[29,48]

Although the etiology of patellofemoral pain is not fully understood, the condition is thought to be multifactorial, including both local and nonlocal factors.[11,22,30,32,34] Local factors are related to the patellofemoral joint and surrounding tissues, such as altered mechanics of the joint and impaired quadriceps function.[9,13] Nonlocal factors are related to the mechanics of the distal and proximal joints, such as increased foot pronation and increased hip adduction and

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medial rotation during weight-bearing tasks.[24,42,46] Theoretically, weakness of the hip abductors, lateral rotators, and extensors is thought to lead to excessive hip adduction and medial rotation, which contributes to altered tibiofemoral and patellofemoral joint kinematics and patellofemoral joint stress.[23]

Traditionally, rehabilitation protocols for treating persons with patellofemoral pain have focused exclusively on local factors, such as the use of knee orthoses (eg, patellar taping and bracing) and strengthening of the quadriceps muscles.[5,6,8,41] Although there is a lack of evidence on the use of knee orthoses,[41] knee strengthening increases patellofemoral joint contact area[6] and reduces pain intensity.[5,15,44] It has been suggested that strengthening of the hip abductors, lateral rotators, and extensors, associated or not with knee strengthening, may reduce excessive hip adduction and medial rotation during weight-bearing activities and decrease patellofemoral joint stress. This suggestion is supported by the reported associations among increased hip adduction and medial rotation and weakness of the hip abductors, lateral rotators, and extensors, a deficiency commonly demonstrated by individuals with patellofemoral pain.[35,42] In fact, recent prospective studies have demonstrated that increased peak hip medial rotation angle during a landing task[5] and greater peak hip adduction angle in recreational runners[30] are risk factors for the development of patellofemoral pain. Therefore, the addition of hip strengthening for the treatment of persons with patellofemoral pain has the potential to reduce pain and improve performance of activities of daily living.

To date, 4 systematic reviews have examined the effects of exercise interventions in individuals with patellofemoral pain.[4,37,39,44] The first review suggested that hip strengthening had a positive effect on pain reduction, with effect sizes ranging from 0.54 to 0.62.[4] The second review found that the addition of hip strengthening decreased pain during activity (mean difference, −2.2; 95% confidence interval [CI]: −3.8, −0.6) and usual pain (mean difference, −1.8; 95% CI: −2.8, −0.8), but did not change functional ability (standardized mean difference [SMD], 0.6; 95% CI: −0.4, 1.6) in comparison to knee strengthening alone.[44] However, the findings of this review were based on 4 clinical trials with substantial statistical heterogeneity (I^2 = 82%-90%). The third review found hip strengthening to be effective for improving pain and patient-reported function, with moderate-to-strong effect sizes. However, the absolute values were not provided, and the inclusion of a nonrandomized trial might have introduced bias into the results.[37] The fourth review included 7 randomized clinical trials and concluded that hip strengthening was effective in reducing pain and improving functional capabilities, without changes in strength, compared to no intervention, placebo intervention, or any other type of treatment.[39] A quantitative description of the results was provided, without the benefit of a meta-analysis.[39]

Given that different trials have been examined in different reviews and that previous reviews have included a few studies with substantial statistical heterogeneity or did not pool the results from different trials, a meta-analysis of the current evidence is warranted. The aim of this systematic review was to examine the efficacy of knee strengthening, associated or not with hip strengthening (from now on referred to as hip and knee strengthening), to increase strength, reduce pain, and improve activity in individuals with patellofemoral pain. The specific research questions were:

1. Does hip and knee strengthening increase strength, reduce pain, and improve activity in individuals with patellofemoral pain? Are any benefits maintained beyond the intervention period?
2. Is hip and knee strengthening more effective than knee strengthening alone for increasing strength, reducing pain, and improving activity in individuals with patellofemoral pain? Are any benefits maintained beyond the intervention period?

To make recommendations based on a high level of evidence, this systematic review included only randomized and/or controlled trials.

METHODS

Identification and Selection of Trials

The review was registered at PROSPERO (CRD42015027762). Searches were conducted in the Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, MEDLINE, PsycINFO, and Physiotherapy Evidence Database (PEDro) databases for relevant studies, without date or language restrictions. The search strategy was registered at PubMed/MEDLINE, and the authors received notifications with potential papers related to this systematic review. Search terms included words related to patellofemoral pain and randomized, quasi-randomized, or controlled trials, and words related to strength training (**APPENDIX A**, available at www.jospt.org). Titles and abstracts were displayed and screened by 2 reviewers to identify relevant studies. Full paper copies of peer-reviewed, relevant papers were retrieved and their reference lists screened to identify further relevant studies. The Methods section of the retrieved papers was extracted and independently reviewed by 2 reviewers using predetermined criteria (**TABLE 1**). Both reviewers were blinded to authors, journal, and results. Disagreement or ambiguities were resolved by consensus.

Assessment of Trial Characteristics

Quality The quality of included trials was assessed by extracting the PEDro scale scores from PEDro (www.pedro.org.au). The PEDro scale is an 11-item scale designed for rating the methodological quality (internal validity and statistical information) of randomized trials. Each item, except for item 1, contributes 1 point to the total score (range,

TABLE 1	Inclusion Criteria
Criterion	**Description**
Design	Randomized and/or controlled trials
Participants	Individuals with patellofemoral pain
Intervention	Experimental intervention is strengthening, in order to increase strength of the posterolateral hip muscles (ie, hip abductors, extensors, and/or lateral rotators)
Outcome measures	Measures of strength, pain intensity, or activity
Comparisons	Hip and knee strengthening versus nothing/placebo Hip and knee strengthening versus knee strengthening alone

0-10 points). Reliability of the total score is 0.68 (95% CI: 0.57, 0.76) for consensus ratings.[26] When a trial was not included in the PEDro database, it was scored by a reviewer who had completed the PEDro scale training tutorial.

Participants Studies had to include individuals with patellofemoral pain. Patellofemoral pain was defined as retropatellar pain (behind the patella) or peripatellar pain (around the patella), mostly occurring when load was put on the knee extensor mechanism, such as when climbing stairs, squatting, running, cycling, or sitting with flexed knees. Studies including participants with other knee conditions, such as Hoffa's syndrome, Osgood-Schlatter syndrome, Sinding-Larsen-Johansson syndrome, iliotibial band friction syndrome, tendinopathies, neuromas, intra-articular pathology (including osteoarthritis and rheumatoid arthritis), traumatic injuries (eg, injured ligaments, meniscal tears, patellar fractures, and patellar luxation), plica syndromes, and more rarely occurring pathologies, were not included.[22,44] The number of participants and their age, level of physical activity, and baseline pain intensity were extracted to assess the similarity of the subject populations among studies.

Intervention The experimental intervention had to consist of a hip- and/or knee-strengthening program using body weight, free weights, machines, or elastic resistance. The intervention had to be of a dose that would be expected to improve strength (ie, it had to involve repetitive and/or effortful muscle contractions), and it had to be stated or implied that the purpose of the intervention was strengthening.[2,40] Session duration, session frequency, program duration, and characteristics of the strength training (ie, muscles, type of exercises, setting, load, and progression) were recorded to assess the similarity of the interventions among the studies. The control intervention was defined according to each research question: (1) to examine the efficacy of hip and knee strengthening, the control intervention could be nothing, placebo, or any other non–lower-limb intervention; (2) to examine the effect of hip and knee strengthening compared with knee strengthening alone, the control intervention could be a single-joint resistance training applied to the knee muscles only.

Outcome Measures Three outcome measures were of interest: strength, pain, and activity. The strength measurement had to be reported as peak force/torque generation and representative of maximum voluntary contraction (eg, manual muscle test or dynamometry). When multiple measures of strength were reported, only measures obtained from the trained muscle(s) were used. If it was appropriate to use the measures from several different muscles targeted in the intervention, then the means and SDs of the individual measurements were summed.[1,28]

The pain measurement had to be reported as pain intensity and based on validated self-reporting methods (eg, visual analog scale or numeric rating scale). When multiple measures of pain intensity were reported in 1 study (eg, pain at rest, worst pain, or pain during activity), the means and SDs of the individual measurements were averaged. Questionnaires examining multiple aspects of pain (eg, pain duration and/or pain frequency) were included when pain intensity was separately reported.

The activity measurement had to be a direct measure of capacity or performance. When multiple measures of activity were reported in 1 study, the measure used to calculate the sample size or the measure that combined more activities was used. Questionnaires examining multiple outcomes (eg, Western Ontario and McMaster Universities Osteoarthritis Index) were used if they were the only available measure of activity. The timing of the measurements of outcomes and the procedure used to measure the different outcomes were recorded to assess the appropriateness of combining studies in the meta-analysis.

Data Analysis

Information about the method (ie, design, participants, intervention, measures) and results (ie, number of participants and mean ± SD of outcomes of interest) was independently extracted by 2 reviewers. Disagreement or ambiguities were resolved by consensus. Where information was not available in the published trials, details were requested from the corresponding author.

The postintervention scores and/or change scores were used to obtain the pooled estimate of the effects of the intervention, immediately postintervention and in the long term (ie, after a period of no intervention), using the fixed-effects model. In the case of significant statistical heterogeneity (I^2>40%),[18] a random-effects model was applied. Post hoc sensitivity analysis was planned when the result of the random-effects model was different from that of the fixed-effects model. The analyses were performed using Review Manager Version 5.3 (The

Nordic Cochrane Centre, Copenhagen, Denmark). For all outcome measures, the critical value for rejecting H_0 was set at a level of .05 (2 tailed). The pooled data for each outcome were reported as the weighted mean difference (95% CI) or SMD (95% CI) between the groups. Standardized mean differences were interpreted as small (less than 0.4), moderate (0.4-0.7), or large (greater than 0.7).[18] Where data of trials could not be included in a pooled analysis, the between-group result was reported.

RESULTS

Flow of Trials Through the Review

The electronic search strategy identified 5053 papers (excluding duplicates). After screening titles, abstracts, and reference lists, 52 potentially relevant full papers were retrieved. Forty failed to meet the inclusion criteria and 2 papers were found after the search update. Therefore, 14 papers were included in this systematic review. One of the papers[17] reported a trial with 3 arms (hip and knee strengthening, knee strengthening, and nonintervention group); therefore, 15 relevant comparisons were reported among the 14 included trials. **FIGURE 1** shows the flow of papers through the review.

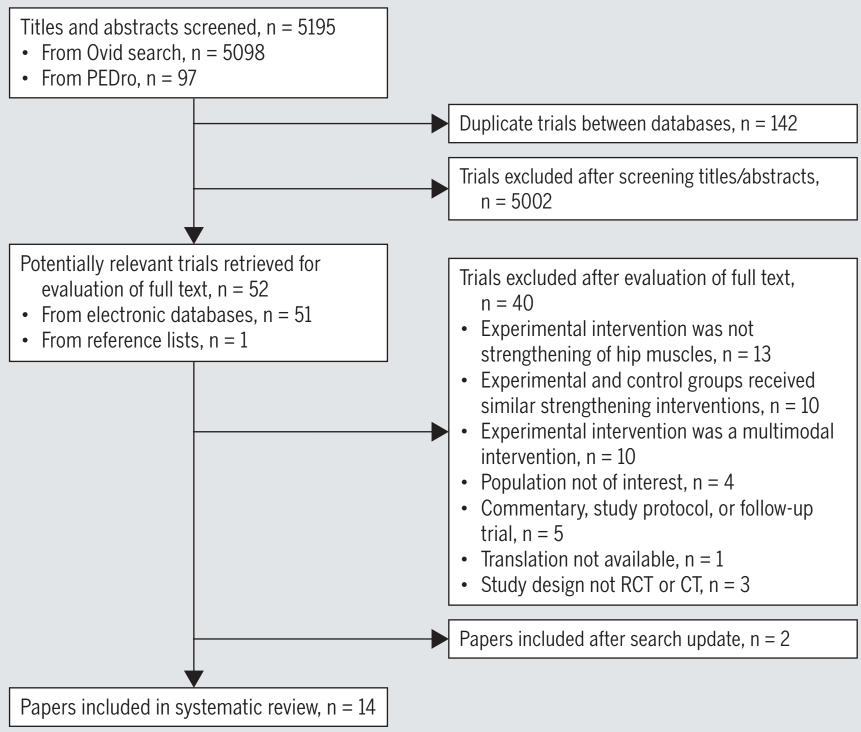


FIGURE 1. Flow of studies through the review. Trials may have been excluded for failing to meet more than 1 inclusion criterion. Abbreviations: CT, controlled trial; PEDro, Physiotherapy Evidence Database; RCT, randomized clinical trial.

Characteristics of Included Trials

The 14 trials involved 673 participants and investigated the effects of hip and knee strengthening for increasing strength (n = 9), reducing pain (n = 14), and improving activity (n = 12) in people with patellofemoral pain (**TABLE 2**). Four trials compared hip and knee strengthening with nothing/placebo, providing data to answer the first study question.[7,17,21,25] Eleven trials compared hip and knee strengthening with knee strengthening alone, providing data to answer the second study question.[3,10,12,14,16,17,19,20,27,36,38] Additional information on 8 papers was requested from the authors.

Quality The mean PEDro score of the trials was 5.8 (range, 3-8) (**TABLE 3**). The majority of trials randomly allocated participants (93%), had similar groups at baseline (86%), had less than a 15% dropout rate (71%), had blinded assessors (57%), and reported between-group differences (86%) and point estimate and variability (93%). However, the majority of trials did not report concealed allocation (57%), and half did not report an intention-to-treat analysis (50%). No trials blinded participants or therapists.

Participants The mean age of the participants ranged from 21 to 35 years across trials. The majority of trials (72%) included participants who reported pain duration of greater than 3 months, with a mean pain intensity ranging from 3 to 8 out of 10 across trials. Four trials included active participants, 6 included sedentary participants, and 4 trials did not report whether the included participants were active or sedentary.

Intervention In all trials, the experimental intervention was strengthening of the hip muscles. In the majority of trials (79%), hip strengthening was accompanied by knee strengthening. The main hip muscle groups targeted in the experimental groups were the lateral rotators (13 trials), abductors (12 trials), and extensors (4 trials). One trial[25] delivered hip strengthening exclusively via functional exercises. Participants undertook training mostly 2 or 3 times per week (9 trials) for an average ± SD of 6 ± 2.5 weeks. Detailed information regarding the type of exercises, load, setting, and progression is provided in **TABLE 2**. The control group received no intervention or placebo intervention in 4 trials, and knee strengthening alone in 11 trials. Four trials delivered additional therapy to both experimental and control groups.

Outcome Measures Measures of strength consisted of maximum voluntary force production obtained during isometric contractions in 4 trials, concentric contractions in 1 trial, eccentric contractions

TABLE 2 CHARACTERISTICS OF INCLUDED TRIALS (N = 14)*

Study	Design	Participants	Intervention: Frequency and Duration	Intervention: Parameters	Outcome Measures
Avraham et al[3]	RCT	n = 20 Age, 35 y Pain duration not reported Pain intensity not reported Activity level not reported	EG: hip and knee strengthening, 30 min, twice per week for 3 wk CG: knee strengthening, 30 min, twice per week for 3 wk Both: TENS and stretching	Muscles: hip lateral rotators and knee muscles Load: not reported Type: body weight Setting: not reported Progression: not reported	Pain: VAS (0-10 cm) Activity: scoring of patellofemoral disorders scale (0-100) Timing: 0, 3 wk
de Marche Baldon et al[10]	RCT	n = 31 Age, 22 ± 3 y Pain duration, 44 mo (range, 3-180 mo) Pain intensity (0-10), 6.4 ± 1.5 Active	EG: hip and knee strengthening, 90-120 min, 3 times per week for 8 wk CG: knee strengthening, 75-90 min, 3 times per week for 8 wk	Muscles: hip abductors, lateral rotators, extensors, and knee and trunk muscles Load: 20%-75% of 1RM Type: body weight, free weights, machines, and elastic resistance Setting: clinics Progression: resistance and/or repetitions increased according to participants' capacity	Pain: VAS (0-10 cm) Strength: dynamometry, Nm/kg Activity: LEFS (0-80) Timing: 0, 8, 20 wk
Clark et al[7]	RCT	n = 27 Age, 28 ± 7 y Pain duration, >3 mo Pain intensity (0-10), 8.0 ± 4.2 Activity level not reported	EG: hip and knee strengthening, 7 times per week for 12 wk CG: nothing Both: education	Muscles: hip abductors, lateral rotators, extensors, and knee muscles Load: body weight Type: body weight Setting: home Progression: difficulty of exercise increased every day	Pain: VAS (0-10 mm) Strength: dynamometry, kgf Activity: WOMAC (0-96) Timing: 0, 12, 48 wk
Dolak et al[12]	RCT	n = 27 Age, 26 ± 6 y Pain duration, 32 ± 34 mo Pain intensity (0-10), 4.4 ± 2.4 Activity level not reported	EG: hip strengthening, 3 times per week for 4 wk CG: knee strengthening, 3 times per week for 4 wk	Muscles: hip abductors, lateral rotators Load: 3% of body weight Type: body weight, free weights Setting: home and clinics Progression: resistance increased every week until 7% of body weight	Pain: VAS (0-10 cm) Strength: dynamometry, Nm/kg Activity: LEFS (0-80) Timing: 0, 4, 12 wk
Ferber et al[14]	RCT	n = 199 Age, 29 ± 7 y Pain duration, 28 ± 35 mo Pain intensity (0-10), 5 ± 1.6 Active	EG: hip strengthening, 3 times per week for 6 wk CG: knee strengthening, 3 times per week for 6 wk	Muscles: hip abductors, lateral rotators, and core muscles Load: 10 maximal repetitions Type: elastic resistance Setting: clinics Progression: sets, repetitions, and/or duration of exercises increased according to participants' feedback and symptoms	Pain: VAS (0-10 cm) Strength: dynamometry, Nm/kg Activity: AKPS (0-100) Timing: 0, 6 wk
Fukuda et al[17]	RCT	n = 64 Age, 25 ± 7 y Pain duration, >3 mo Pain intensity (0-10), 4.8 ± 2.3 Sedentary	EG: hip and knee strengthening, 3 times per week for 4 wk CG 1: nothing CG 2: knee strengthening, 3 times per week for 4 wk	Muscles: hip abductors, lateral rotators, and knee muscles Load: 70% of 1RM or 10RM Type: free weights, machines, and elastic resistance Setting: clinics Progression: resistance adjusted to 70% of maximal strength every week	Pain: NPRS (0-10) Activity: LEFS (0-80) Timing: 0, 4 wk
Fukuda et al[16]	RCT	n = 49 Age, 23 ± 3 y Pain duration, 22 ± 18 mo Pain intensity (0-10), 6.3 ± 1.2 Sedentary	EG: hip and knee strengthening, 3 times per week for 4 wk CG: knee strengthening, 3 times per week for 4 wk	Muscles: hip abductors, lateral rotators, extensors, and knee muscles Load: 70% of 1RM Type: body weight, free weights, machines, and elastic resistance Setting: clinics Progression: resistance adjusted to 70% of maximal strength every week	Pain: NPRS (0-10) Activity: LEFS (0-80) Timing: 0, 12, 24 wk

Table continues on page 24.

TABLE 2 Characteristics of Included Trials (n = 14)*(continued)

Study	Design	Participants	Intervention: Frequency and Duration	Intervention: Parameters	Outcome Measures
Ismail et al[19]	RCT	n = 32 Age, 21 ± 3 y Pain duration, >1.5 mo Pain intensity (0-10), 4.9 ± 1.7 Activity level not reported	EG: hip and knee strengthening, 3 times per week for 6 wk CG: knee strengthening, 3 times per week for 6 wk	Muscles: hip abductors, lateral rotators, and knee muscles Load: not reported Type: body weight and elastic resistance Setting: clinics Progression: not reported	Pain: VAS (0-10 cm) Strength: dynamometry, Nm/kg Activity: scoring of patellofemoral disorders scale (0-100) Timing: 0, 6 wk
Khayambashi et al[21]	RCT	n = 28 Age, 30 ± 6 y Pain duration, >6 mo Pain intensity (0-10), 7.3 ± 1.9 Sedentary	EG: hip strengthening, 30 min, 3 times per week for 8 wk CG: placebo	Muscles: hip abductors, lateral rotators Load: elastic tubing color Type: elastic resistance Setting: gym Progression: resistance increased every 2 wk	Pain: VAS (0-10 cm) Strength: dynamometry, N/kg Activity: WOMAC (0-96) Timing: 0, 8, 24 wk
Khayambashi et al[20]	CT	n = 36 Age, 28 ± 7 y Pain duration, >6 mo Pain intensity (0-10), 7.3 ± 1.7 Sedentary	EG: hip and knee strengthening, 30 min, 3 times per week for 8 wk CG: knee strengthening, 30 min, 3 times per week for 8 wk	Muscles: hip abductors, lateral rotators Load: elastic tubing color Type: elastic resistance Setting: gym Progression: resistance increased every 2 wk	Pain: VAS (0-10 cm) Activity: WOMAC (0-96) Timing: 0, 8, 24 wk
Lun et al[25]	RCT	n = 64 Age, 35 ± 11 y Pain duration, 9 ± 6 mo Pain intensity (0-10), 4.6 ± 2.9 Active	EG: hip and knee strengthening not reported CG: nothing Both: patellar brace	Muscles: hip and knee muscles via squats Load: not reported Type: body weight Setting: home Progression: exercises changed every 5 d	Pain: VAS (0-10 cm) Activity: knee function scale (0-53) Timing: 0, 3, 6, 12 wk
Nakagawa et al[27]	RCT	n = 14 Age, 24 ± 6 y Pain duration, >1 mo Pain intensity (0-10), 4.6 ± 2.8 Active	EG: hip and knee strengthening, 5 times per week for 6 wk CG: knee strengthening, 5 times per week for 6 wk	Muscles: hip abductors, lateral rotators, and knee and transversus muscles Load: not reported Type: body weight and elastic resistance Setting: home and clinics Progression: resistance increased every 2 wk	Pain: VAS (0-10 cm) Strength: dynamometry, Nm/kg Timing: 0, 6 wk
Razeghi et al[36]	RCT	n = 32 Age, 23 ± 3 y Pain duration, >1 mo Pain intensity (0-10), 6.5 ± 1.4 Sedentary	EG: hip and knee strengthening for 4 wk CG: knee strengthening for 4 wk	Muscles: hip abductors and adductors, lateral and medial rotators, flexors and extensors, and knee muscles Load: not reported Type: not reported Setting: not reported Progression: resistance increased according to McQueen progressive resistive technique	Pain: VAS (0-10 cm) Strength: dynamometry, % Timing: 0, 4 wk
Şahin et al[38]	RCT	n = 50 Age, 34 ± 6 y Pain duration, >3 mo Pain intensity (0-10), 3 (3-4) Sedentary	EG: hip and knee strengthening, 30 sessions, 5 times per week for 6 wk CG: knee strengthening, 30 sessions, 5 times per week for 6 wk Both: education	Muscles: hip abductors, lateral rotators, and knee muscles Load: 10 maximal repetitions Type: elastic resistance Setting: clinics Progression: not reported	Pain: VAS (0-10 cm) Strength: dynamometry, Nm/kg Activity: AKPS (0-100) Timing: 0, 6, 12 wk

Abbreviations: 1RM, 1-repetition maximum; 10RM, 10-repetition maximum; AKPS, Anterior Knee Pain Scale; CG, control group; CT, controlled trial; EG, experimental group; LEFS, Lower Extremity Functional Scale; NPRS, numeric pain-rating scale; RCT, randomized clinical trial; TENS, transcutaneous electrical nerve stimulation; VAS, visual analog scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.
**Groups and outcome measures listed are those that were analyzed in this systematic review; there may have been other groups or measures in the paper.*

in 2 trials, or concentric and eccentric contractions in 1 trial. One trial[7] did not report the type of contraction used to measure strength. Measures of pain intensity were based on validated self-reporting methods obtained using a numeric rating scale (0-10) in 2 trials and a visual analog scale (0-10) in 12 trials. Pain intensity was reported as "worst pain" in 4 trials, "pain in activity" (eg, ascending stairs or walking) in 4 trials, or "pain in different situations" (eg, pain at rest, worst pain, and pain in activity) in 4 trials. Two trials[3,36] did not report the characteristics of pain measurement. Measures of activity were always based on questionnaires that reflected performance in activities of daily living. The

TABLE 3 PEDro Criteria and Scores for the Included Papers (n = 14)

Study	Item*										Total (0-10)
	1	2	3	4	5	6	7	8	9	10	
Avraham et al[3]	Y	N	N	N	N	Y	N	N	Y	N	3
de Marche Baldon et al[10]	Y	Y	Y	N	N	N	Y	Y	Y	Y	7
Clark et al[7]	Y	N	Y	N	N	Y	Y	Y	Y	Y	7
Dolak et al[12]	Y	N	Y	N	N	Y	N	Y	Y	Y	6
Ferber et al[14]	Y	Y	Y	N	N	N	N	Y	Y	Y	6
Fukuda et al[17]	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Fukuda et al[16]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Ismail et al[19]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Khayambashi et al[21]	Y	N	Y	N	N	N	Y	N	Y	Y	5
Khayambashi et al[20]	N	N	Y	N	N	N	Y	N	Y	Y	4
Lun et al[25]	Y	N	Y	N	N	N	N	N	N	Y	3
Nakagawa et al[27]	Y	Y	Y	N	N	Y	Y	Y	N	Y	7
Razeghi et al[36]	Y	N	N	N	N	N	Y	N	Y	Y	4
Şahin et al[38]	Y	N	Y	N	N	Y	Y	N	Y	Y	6

Abbreviations: N, no; PEDro, Physiotherapy Evidence Database; Y, yes.
**Scored items: 1, Random allocation; 2, Concealed allocation; 3, Groups similar at baseline; 4, Participant blinding; 5, Therapist blinding; 6, Assessor blinding; 7, less than 15% dropout rate; 8, Intention-to-treat analysis; 9, Between-group difference reported; 10, Point estimate and variability reported.*

specific instruments used in each trial are listed in **TABLE 2**.

Effect of Hip and Knee Strengthening

Strength The overall effect of hip and knee strength training on strength was examined by pooling postintervention data from 2 trials (n = 70)[7,21] with a mean PEDro scale score of 6. There was substantial statistical heterogeneity (I^2 = 82%), indicating that the variation between the results of the trials was above the variation expected by chance. When a random-effects model was applied, hip and knee strengthening did not significantly change strength compared with no strengthening/placebo (SMD, 0.8; 95% CI: –0.4, 2.1) (**FIGURE 2**). No trials examined the effect of intervention beyond the intervention period.

Pain The effect of hip and knee strengthening on pain was examined by pooling postintervention/change score data from 3 trials (n = 112)[7,17,21] with a mean PEDro scale score of 6.3. There was substantial statistical heterogeneity (I^2 = 81%), indicating that the variation between the results of the trials was above the variation expected by chance. When a random-effects model was applied, hip and knee strengthening significantly reduced pain by 3.3 points out of 10 (95% CI: –5.6, –1.1) compared with no strengthening/placebo (**FIGURE 3**). The maintenance of benefits beyond the intervention period was examined in 1 trial (PEDro scale score, 7/10).[7] The mean difference between groups after 1 year was –3.9 points out of 10 (95% CI: –7.4, –0.4) in favor of the experimental group.

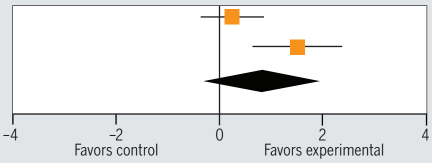
Activity The effect of hip and knee strengthening on activity was examined by pooling postintervention data from 3 trials (n = 114)[7,17,21] with a mean PEDro scale score of 6.3. There was substantial statistical heterogeneity (I^2 = 90%). When a random-effects model was applied, hip and knee strengthening significantly improved activity, with an effect size of 1.4 (95% CI: 0.03, 2.8), compared with no strengthening/placebo (**FIGURE 4**). The maintenance of benefits beyond the intervention period was examined in 1 trial (PEDro scale score, 7/10).[7] The mean difference between groups after 1 year was –12.0 out of 96 (95% CI: –24.7, 0.7) in favor of the experimental group.

Effect of Hip and Knee Strengthening Compared With Knee Strengthening Alone

Strength The effect of hip and knee strengthening, compared with knee strengthening alone, on strength was examined by pooling postintervention data from 6 trials (n = 359)[10,12,14,19,27,38] with a mean PEDro scale score of 6.7. Hip and knee strengthening did not significantly change strength compared with knee strengthening alone (SMD, 0.2; 95% CI: –0.1, 0.4; I^2 = 0%) (**FIGURE 5**). One trial[36] did not provide viable data to be included in the meta-analysis. The effect of intervention beyond the intervention period was examined in 2 trials.[12,38] No significant change was found in strength of the hip and knee muscles between the groups 4 weeks beyond the intervention period (mean difference, 0.4 Nm/kg; 95% CI: –0.4, 1.3)[12] or 6 weeks beyond the intervention period (mean difference, –2 Nm/kg; 95% CI: –10, 6).[38]

Hip/Knee Strengthening Versus Nothing/Placebo—Immediate: Strength

Study	Experimental Group Mean ± SD	Experimental Group Total, n	Control Group Mean ± SD	Control Group Total, n	Weight	SMD IV, Random (95% Confidence Interval)
Clark et al[7]	314 ± 178	20	269.3 ± 157.3	22	53.0%	0.26 (−0.35, 0.87)
Khayambashi et al[21]	13.5 ± 2.6	14	9.5 ± 2.5	14	47.0%	1.52 (0.67, 2.38)
Total		34		36	100.0%	0.85 (−0.38, 2.09)

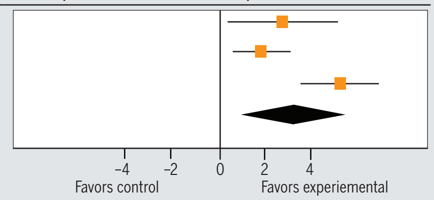


Abbreviations: IV, independent variable; SMD, standardized mean difference.

FIGURE 2. Standardized mean differences of the effect of hip and knee strengthening versus nothing/placebo on strength, immediately after the intervention (n = 70).

Hip/Knee Strengthening Versus Nothing/Placebo—Immediate: Pain

Study	Experimental Group Mean ± SD	Experimental Group Total, n	Control Group Mean ± SD	Control Group Total, n	Weight	MD IV, Random (95% Confidence Interval)
Clark et al[7]	5.8 ± 3.8	22	3.0 ± 3.9	20	28.7%	2.80 (0.47, 5.13)
Fukuda et al[17]	4.55 ± 2.40	23	2.65 ± 1.65	21	37.2%	1.90 (0.69, 3.11)
Khayambashi et al[21]	6.7 ± 2.5	14	1.4 ± 1.9	14	34.1%	5.30 (3.66, 6.94)
Total		59		55	100.0%	3.32 (1.07, 5.56)

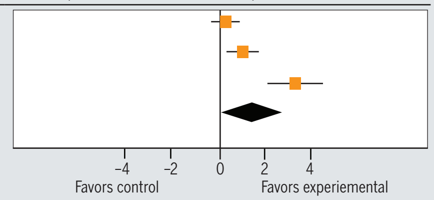


Abbreviations: IV, independent variable; MD, mean difference.

FIGURE 3. Mean differences of the effect of hip and knee strengthening versus nothing/placebo on pain intensity (0-10 scale), immediately after intervention (n = 114).

Hip/Knee Strengthening Versus Nothing/Placebo—Immediate: Activity

Study	Experimental Group Mean ± SD	Experimental Group Total, n	Control Group Mean ± SD	Control Group Total, n	Weight	SMD IV, Random (95% Confidence Interval)
Clark et al[7]	13.8 ± 15.8	22	10.0 ± 11.8	20	35.3%	0.27 (−0.34, 0.87)
Fukuda et al[17]	65.7 ± 13.5	21	51.2 ± 15.1	21	35.0%	0.99 (0.35, 1.64)
Khayambashi et al[21]	59.9 ± 12.6	14	10.7 ± 16.1	14	29.7%	3.30 (2.11, 4.50)
Total		57		55	100.0%	1.42 (0.03, 2.82)



Abbreviations: IV, independent variable; SMD, standardized mean difference.

FIGURE 4. Standardized mean differences of the effect of hip and knee strengthening versus nothing/placebo on activity, immediately after intervention (n = 112).

Pain The effect of hip and knee strengthening, compared with knee strengthening alone, on pain intensity was examined by pooling postintervention/change score data from 10 trials (n = 517)[10,12,14,16,17,19,20,27,36,38] with a mean PEDro scale score of 6.3. There was substantial statistical heterogeneity (I^2 = 82%). When a random-effects model was applied, hip and knee strengthening significantly reduced pain by 1.5 points out of 10 (95% CI: −2.3, −0.8) compared with knee strengthening alone (**FIGURE 6**).

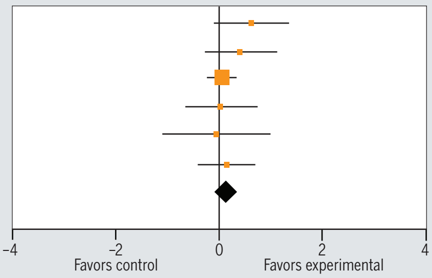
Reduction of pain beyond the intervention period was examined by pooling postintervention/change score data from 5 trials[10,12,16,20,38] (n = 191). Hip and knee strengthening resulted in a significant decrease in pain intensity of 1.9 points out of 10 (95% CI: −3.1, −0.7; random effects) compared with knee strengthening alone 12.0 ± 5.7 weeks beyond the intervention period (**FIGURE 7**).

Activity The effect of hip and knee strengthening, compared with knee strengthening alone, on self-reported activity level was examined by pooling postintervention data from 8 trials[10,12,14,16,17,19,20,38] (n = 471) with a mean PEDro scale score of 6.5. There was substantial statistical heterogeneity (I^2 = 87%). When a random-effects model was applied, hip and knee strengthening significantly improved activity, with an effect size of 0.7 (95% CI: 0.2, 1.3), compared with knee strengthening alone (**FIGURE 8**).

Maintenance of activity beyond the intervention period was examined by

Hip/Knee Strengthening Versus Knee Strengthening Alone—Immediate: Strength

Study	Experimental Group		Control Group		Weight	SMD IV, Random (95% Confidence Interval)
	Mean ± SD	Total, n	Mean ± SD	Total, n		
de Marche Baldon et al[10]	1.77 ± 0.20	15	1.6 ± 0.3	16	8.3%	0.65 (–0.08, 1.37)
Dolak et al[12]	5.2 ± 1.2	17	4.6 ± 1.5	16	9.1%	0.43 (–0.26, 1.12)
Ferber et al[14]	2.66 ± 0.95	111	2.59 ± 1.02	88	55.5%	0.07 (–0.21, 0.35)
Ismail et al[19]	2 .00 ± 0.75	16	1.92 ± 1.90	16	9.1%	0.05 (–0.64, 0.75)
Nakagawa et al[27]	160.2 ± 45.2	7	161.7 ± 35.6	7	4.0%	–0.03 (–1.08, 1.01)
Şahin et al[38]	48.5 ± 15.6	25	45.9 ± 15.7	25	14.1%	0.16 (–0.39, 0.72)
Total		191		168	100.0%	0.16 (–0.05, 0.37)

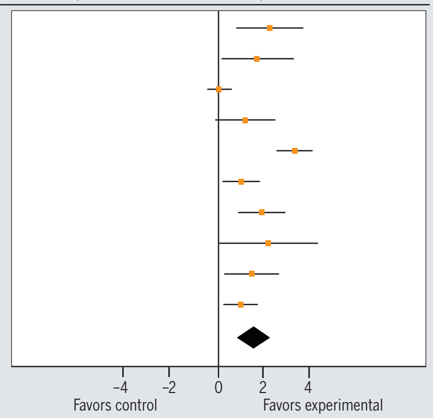


Abbreviations: IV, independent variable; SMD, standardized mean difference.

FIGURE 5. Standardized mean differences of the effect of hip and knee strengthening versus knee strengthening alone on strength, immediately after intervention (n = 359).

Hip/Knee Strengthening Versus Knee Strengthening Alone—Immediate: Pain

Study	Experimental Group		Control Group		Weight	MD IV, Random (95% Confidence Interval)
	Mean ± SD	Total, n	Mean ± SD	Total, n		
de Marche Baldon et al[10]	5.2 ± 1.6	16	3 ± 2.4	15	8.7%	2.20 (0.75, 3.65)
Dolak et al[12]	4.1 ± 2.5	16	2.4 ± 2.0	17	8.3%	1.70 (0.15, 3.25)
Ferber et al[14]	1.99 ± 2.05	88	1.96 ± 1.92	111	12.2%	0.03 (–0.53, 0.59)
Fukuda et al[17]	2.4 ± 2.3	20	1.25 ± 1.90	21	9.3%	1.15 (–0.14, 2.44)
Fukuda et al[16]	4.6 ± 1.6	24	1.3 ± 1.1	25	11.5%	3.30 (2.53, 4.07)
Ismail et al[19]	3.2 ± 0.9	16	2.2 ± 1.3	16	11.4%	1.00 (0.23, 1.77)
Khayambashi et al[20]	5.5 ± 1.6	18	3.6 ± 1.4	18	10.6%	1.90 (0.92, 2.88)
Nakagawa et al[27]	3.00 ± 2.65	7	0.80 ± 0.95	7	6.4%	2.20 (0.11, 4.29)
Razeghi et al[36]	4.81 ± 1.79	16	3.37 ± 1.50	16	10.0%	1.44 (0.30, 2.58)
Şahin et al[38]	2.0 ± 1.1	25	1.0 ± 1.5	25	11.6%	1.00 (0.27, 1.73)
Total		246		271	100.0%	1.54 (0.80, 2.27)

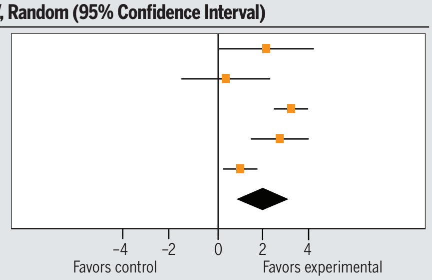


Abbreviations: IV, independent variable; MD, mean difference.

FIGURE 6. Mean difference of the effect of hip and knee strengthening versus knee strengthening alone on pain intensity (0-10 scale), immediately after intervention (n = 517).

Hip/Knee Strengthening Versus Knee Strengthening Alone—Beyond Intervention Period: Pain

Study	Experimental Group		Control Group		Weight	MD IV, Random (95% Confidence Interval)
	Mean ± SD	Total, n	Mean ± SD	Total, n		
de Marche Baldon et al[10]	5.7 ± 2.3	16	3.6 ± 3.3	15	15.1%	2.10 (0.09, 4.11)
Dolak et al[12]	2.4 ± 2.3	11	2.1 ± 2.5	14	15.9%	0.30 (–1.59, 2.19)
Fukuda et al[16]	4.15 ± 1.40	24	0.95 ± 1.00	25	24.3%	3.20 (2.52, 3.88)
Khayambashi et al[20]	5.64 ± 1.99	18	2.92 ± 1.72	18	20.7%	2.72 (1.50, 3.94)
Şahin et al[38]	2.0 ± 1.1	25	1.0 ± 1.5	25	24.0%	1.00 (0.27, 1.73)
Total		94		97	100.0%	1.95 (0.75, 3.14)

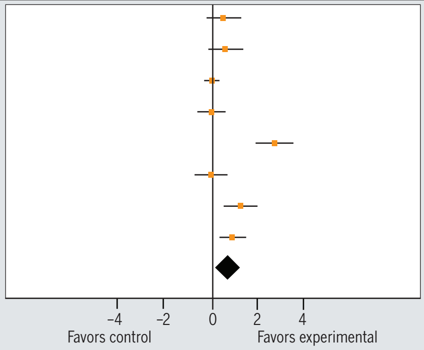


Abbreviations: IV, independent variable; MD, mean difference.

FIGURE 7. Mean difference of the effect of hip and knee strengthening versus knee strengthening alone on pain intensity (0-10 scale), beyond the intervention period (n = 191).

Hip/Knee Strengthening Versus Knee Strengthening Alone—Immediate: Activity

Study	Experimental Group Mean ± SD	Experimental Group Total, n	Control Group Mean ± SD	Control Group Total, n	Weight	SMD IV, Random (95% Confidence Interval)
de Marche Baldon et al[10]	74.3 ± 4.6	15	70.6 ± 8.0	16	12.1%	0.55 (–0.17, 1.27)
Dolak et al[12]	67 ± 11	17	59 ± 14	16	12.2%	0.62 (–0.08, 1.32)
Ferber et al[14]	88.0 ± 11.2	111	87.7 ± 10.5	88	14.4%	0.03 (–0.25, 0.31)
Fukuda et al[17]	65.7 ± 13.5	21	65.6 ± 14.5	20	12.7%	0.01 (–0.61, 0.62)
Fukuda et al[16]	74.1 ± 5.6	25	49.4 ± 11.2	24	11.5%	2.76 (1.96, 3.56)
Ismail et al[19]	85.1 ± 6.2	16	85.0 ± 6.7	16	12.2%	0.02 (–0.68, 0.71)
Khayambashi et al[20]	21.9 ± 16.5	18	6.2 ± 3.9	18	12.0%	1.28 (0.56, 2.01)
Şahin et al[38]	85.4 ± 5.8	25	79.1 ± 7.6	25	12.9%	0.92 (0.33, 1.50)
Total		248		223	100.0%	0.74 (0.17, 1.31)

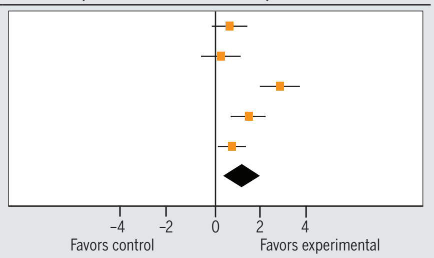


Abbreviations: IV, independent variable; SMD, standardized mean difference.

FIGURE 8. Standardized mean differences of the effect of hip and knee strengthening versus knee strengthening alone on activity, immediately after intervention (n = 471).

Hip/Knee Strengthening Versus Knee Strengthening Alone—Beyond Intervention Period: Activity

Study	Experimental Group Mean ± SD	Experimental Group Total, n	Control Group Mean ± SD	Control Group Total, n	Weight	SMD IV, Random (95% Confidence Interval)
de Marche Baldon et al[10]	74.9 ± 3.9	15	70.4 ± 8.4	16	20.1%	0.66 (–0.06, 1.39)
Dolak et al[12]	70 ± 10	12	67 ± 11	10	19.1%	0.28 (–0.57, 1.12)
Fukuda et al[16]	72.4 ± 6.1	25	47.7 ± 10.5	24	19.4%	2.85 (2.03, 3.66)
Khayambashi et al[20]	23.16 ± 14.15	18	6.94 ± 5.70	18	20.0%	1.47 (0.72, 2.22)
Şahin et al[38]	83.0 ± 6.8	25	77.9 ± 6.6	25	21.4%	0.75 (0.17, 1.32)
Total		95		93	100.0%	1.19 (0.37, 2.01)



Abbreviations: IV, independent variable; SMD, standardized mean difference.

FIGURE 9. Standardized mean differences of the effect of hip and knee strengthening versus knee strengthening alone on activity, beyond the intervention period (n = 188).

pooling postintervention data from 5 trials[10,12,16,20,38] (n = 188). Hip and knee strengthening resulted in a significant improvement in activity, with an effect size of 1.2 (95% CI: 0.4, 2.0; random effects), compared with knee strengthening alone 12 ± 5.7 weeks beyond the intervention period (**FIGURE 9**).

DISCUSSION

This systematic review provides evidence that hip and knee strengthening is effective in reducing pain and improving activity in individuals with patellofemoral pain. The review also indicated that hip and knee strengthening results in greater decrease in pain and improvement in activity compared to knee strengthening alone. Importantly, benefits were maintained beyond the intervention period. Interestingly, the meta-analyses indicated that hip and knee strengthening did not significantly change strength when compared with no exercise/placebo intervention or with knee strengthening alone.

The nonsignificant change in strength found in this review may be explained by the fact that the strengthening interventions were not of sufficient duration and/or intensity. Although the literature indicates a rapid increase in neurological activation of the motor units during the initial phases of strength training, most of the muscle adaptations occur after 8 to 12 weeks of training.[32] The average duration of the strength training in this review was 6 weeks. Only 3 trials,[7,10,21] which investigated 8 to 12 weeks of hip and knee strengthening, provided data regarding strength measures, and their results were considerably higher (SMD, 0.8; 95% CI: 0.1, 1.4; random effects) compared with the pooled effects found in the present review.

Although the strengthening interventions outlined in the reviewed trials were characterized as progressive, they were not administered at the intensity recommended by the American College of Sports Medicine.[2] For example, 1 trial[12] investigated a strengthening program with a load equivalent to 3% of the participant's body weight, when the American College of Sports Medicine guidelines suggest a load of 60% to 70% of 1-repetition maximum for novices.[2] In addition, 5 trials did not report the load applied during strength training. Unfortunately, the majority of trials (9 trials) did not report the duration of the intervention sessions, which could reflect important training properties such as volume of training, contraction velocity, or rest intervals. In summary, the current evidence is insufficient to support or refute the efficacy of strength training to increase muscle strength in people with patellofemoral pain. Further randomized clinical trials, with appropriate training duration and intensity as well as appropriate sample sizes, are warranted.

Despite the lack of strength increases, hip and knee strengthening exercises significantly decreased pain intensity and improved activity in people with patellofemoral pain, with results being maintained beyond the intervention period. The meta-analyses indicated that hip and knee strengthening decreased pain intensity by 3.3 points compared with no exercise/placebo, and by 1.5 points compared with knee strengthening alone. According to Ostelo et al,[31] the cutoff value for minimal important change in pain is 1.5 points (or 30% improvement from baseline). Because the average ± SD pain intensity of the participants in the present review was 5.3 ± 2.5 points, the changes after intervention represent, respectively, 60% and 30% decreases in pain intensity, which are sufficient to be considered clinically meaningful.[31] The meta-analyses also indicated that hip and knee strengthening had a large positive effect on self-reported activity (SMD, 1.4) compared with no exercise/placebo, and a moderate positive effect (SMD, 0.7) compared with knee strengthening alone.

Improvements in pain and activity could be related to the inclusion of weight-bearing exercises (eg, squats), which might have had positive effects on other variables related to patellofemoral syndrome, such as lower-limb pattern of motion[47] and ankle flexibility.[33] In addition, the strength training also may have increased hip and knee muscle endurance, as training intensity and repetitions, in the majority of the trials, were delivered according to the recommended parameters for endurance training.[2] A recent study demonstrated that people with patellofemoral pain exhibit diminished hip muscle endurance compared with healthy controls.[43] However, these hypotheses are speculative at this point, and further research is needed to better understand the effects of strengthening exercises on strength outcomes.

The results of our review are in accordance with a previous Cochrane meta-analysis[44] that demonstrated that hip and knee strengthening decreased pain intensity (mean difference, −1.8; 95% CI: −2.8, −0.8), and add evidence regarding the efficacy of strengthening on self-reported activity. Therefore, this review provides additional evidence on the effect of hip and knee strengthening, as the conclusions are based on meta-analyses of 13 randomized trials and 1 controlled trial of reasonable quality. Furthermore, the results indicate that the decrease in pain intensity and improvements in activity were maintained beyond the intervention period, with moderate-to-large effect sizes, suggesting that benefits were incorporated into daily life.

This systematic review has some limitations. Given that a score of 8 was likely to be the maximum achievable PEDro scale score, owing to the difficulty in blinding therapists or participants, the mean PEDro scale score of 5.8 for the 14 included trials represents moderate quality, suggesting that the findings were credible. Other sources of bias were lack of reporting concealed allocation and whether an intention-to-treat analysis was undertaken. Additionally, the number of participants per group (mean, 24; range, 7-100) was quite low, opening the results to small-trial bias. It is recommended that future randomized clinical trials provide appropriate sample-size calculations so that further systematic reviews can plan sensitivity analyses based on the number of participants.

The current meta-analyses included studies that provided hip strength training and hip and knee strength training to the experimental group, which could be considered a confounding factor. However, the exclusion of the 2 studies[12,14] that provided hip strengthening alone did not change the effects on strength (SMD, 0.2; 95% CI: −0.1, 0.6), pain intensity (mean difference, −1.8; 95% CI: −2.4, −1.1), and activity (SMD, 0.9; 95% CI: 0.2, 1.6). At this time, there is insufficient evidence to indicate that hip strengthening alone is more effective than knee strengthening. Therefore, it is suggested that clinicians provide both hip and knee strengthening to decrease pain and improve activity in people with patellofemoral pain.

Another confounding factor could be the inclusion of 3 studies[10,14,27] that provided trunk muscle training (eg, transversus abdominis). However, the exclusion of these studies from the meta-analyses, again, did not change the effects on strength (SMD, 0.2; 95% CI: −0.2, 0.6), pain intensity (mean difference, −1.6; 95% CI: −2.4, −0.9), and activity (SMD, 0.9; 95% CI: 0.2, 1.7). Based on this information, further systematic reviews should plan subgroup analyses.

Apart from the above-noted limitations, this systematic review has several strengths. Heterogeneity among the trials pooled in the meta-analyses, based on a random-effects model, was low. Overall, the included trials were similar in their clinical characteristics. Most of the trials included adults with moderate-to-high levels of pain intensity, lasting for more than 3 months. Although most of the trials failed to report the session duration, they provided similar session frequencies (mean ± SD, 3.5 ± 1.4 per week) and program durations (mean ± SD, 6.0 ± 2.5 weeks). In addition, this systematic review included 4 recent randomized trials since the last review was published,[39] and also investigated whether the benefits of intervention are maintained beyond the intervention period.

CONCLUSION

This systematic review with meta-analyses provides evidence that hip and knee strengthening is not only effective, but also superior to knee strengthening alone, for decreasing pain intensity and improving activity in people with patellofemoral pain. The results of the meta-analyses, based on 14 trials, indicated that strength training of the hip muscles, accompanied by strengthening of the knee muscles, 3 times a week for 6 weeks can be expected to decrease pain and improve activity in people with moderate-to-high levels of patellofemoral pain. The training benefits are maintained beyond the intervention period. Future studies, with appropriate training duration and intensity, are recommended to elucidate the effects of hip and knee strengthening on increasing strength. ◉

KEY POINTS

FINDINGS: Hip and knee strengthening is not only effective, but is also superior to knee strengthening alone for decreasing pain intensity and improving activity in people with patellofemoral pain. These results were maintained beyond the intervention period.

IMPLICATIONS: Strength training of the hip muscles, accompanied by strengthening of knee muscles, should be included in clinical management of individuals with patellofemoral pain in order to reduce pain and improve activity.

CAUTION: Strengthening interventions were not of sufficient duration and/or intensity, and there is insufficient evidence to support or refute their efficacy in improving muscle strength.

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APPENDIX A

SEARCH STRATEGY

Databases: Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, Ovid MEDLINE, PsycINFO, PEDro.

1. exp patellofemoral pain syndrome/ (549)
2. patella/ or exp knee joint/ or knee/ (62198)
3. arthralgia/ or pain/ (142584)
4. anterior knee pain.tw. (1127)
5. ((patell* or femoropatell* or femoro-patell* or retropatell*) adj2 (pain or syndrome or dysfinction)).tw. (1869)
6. ((lateral compression or lateral facet or lateral pressure or odd facet) adj2 syndrome).tw. (25)
7. ((chondromalac* or chondropath* or chondrosis) adj2 (knee*1 or patell* or femoropatell* or femoro-patell* or retropatell*)).tw. (534)
8. chondromalacia patellae/ (66)
9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 (202018)
10. randomized controlled trial.mp. or exp randomized controlled trial/ (487814)
11. random allocation.mp. or exp random allocation/ (107923)
12. double-blind method.mp. or exp double-blind method/ (235921)
13. single-blind method.mp. or exp single-blind method/ (33399)
14. randomized controlled trials.mp. (128290)
15. clinical trial.mp. or exp clinical trial/ (931625)
16. exp$ clinical trials.mp. (814)
17. (clinic$ adj trial$).mp. (945789)
18. ((singl$ or doubl$ or treb$ or tripl$) adj (blind$ or mask$)).mp. (388475)
19. exp clinical trials as topic/ or placebo.mp. or exp placebo effect/ or exp placebos/ (623702)
20. (randomised controlled trial or randomised clinical trial).mp. (31292)
21. randomly allocated.mp. (35345)
22. 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 (1640886)
23. exp exercise therapy/ or exercise.mp. or exp exercise/ (341453)
24. rehabilitation.mp. or exp rehabilitation/ (327345)
25. (physical therapy or physiotherapy).mp. (51147)
26. resistance training.mp. or exp resistance training/ or exp weight lifting/ (12190)
27. strength$.mp. (341202)
28. (eccentric or concentric or isometric).mp. (51502)
29. 23 or 24 or 25 or 26 or 27 or 28 (985812)
30. 9 and 22 and 29 (5151)
31. limit 30 to human [Limit not valid in CCTR,CDSR; records were retained] (5098)

PEDro

<u>Abstract and Title</u>

Search 1: knee anterior pain + hip + strengthening
Search 2: knee pain + hip muscles
Search 3: knee pain + hip + strength
Search 4: patellofemoral pain syndrome
When searching: match all search terms (AND)

APPENDIX B

EXCLUDED PAPERS

Study	Reasons for Exclusion*						
	1	2	3	4	5	6	7
Almeida et al 2015							✓
Bakhtiary and Fatemi 2008			✓				
Bolgla et al 2015							✓
Balci et al 2009			✓				
Collins et al 2009	✓						
Coppack et al 2011				✓			
Crossley et al 2002					✓		
Crossley et al 2003						✓	
Cowan et al 2002					✓		
Denton et al 2005			✓				
Dursun et al 2002					✓		
Halabchi et al 2015					✓		
Harrison et al 1999	✓				✓		
Herbst et al 2015							✓
Hott et al 2015						✓	
Kannus et al 1999	✓						
Karakus et al 2014			✓				
Kim et al 2013				✓			
Linschoten et al 2009					✓		
Mazloum and Rahnama 2014		✓					
Motealleh et al 2016	✓						
Moyano et al 2013	✓						
Osteras et al 2013a			✓				
Osteras et al 2013b						✓	
Palmer et al 2015				✓			
Qiu et al 2006	✓		✓				
Rathleff et al 2012					✓		
Rathleff et al 2016					✓		
Roush et al 2000					✓		
Scheider et al 2001	✓						
Song et al 2009	✓						
Thomas et al 2002				✓			
Thomas et al 2005	✓						
Vicenzino et al 2008						✓	
Whittingham et al 2004			✓				
Witrouw et al 2000	✓		✓				
Witvrouw et al 2003	✓		✓				
Witvrouw et al 2004	✓		✓			✓	
Yilmaz et al 2015	✓						
Yip et al 2006					✓		

**(1) Experimental intervention was not strengthening or did not include hip muscles (abductors, lateral rotators, or extensors); (2) Translation of paper was not available; (3) Both experimental and control groups received similar strengthening interventions; (4) Population was not composed of participants with patellofemoral pain syndrome; (5) Experimental intervention was a multimodal intervention; (6) Paper was a commentary, study protocol, or follow-up trial; (7) Design was not a randomized or controlled trial.*