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Effects of Physical Therapist–Guided Quadriceps-Strengthening Exercises for the Treatment of Patellofemoral Pain Syndrome: A Systematic Review

STUDY DESIGN: Systematic literature review.

OBJECTIVE: To summarize the evidence for physical therapist–guided quadriceps-strengthening exercises as a treatment for patellofemoral pain syndrome.

BACKGROUND: Although quadriceps strengthening is often included in the plan of care for patellofemoral pain syndrome, a systematic review published in 2003 found only limited evidence that exercise was more effective than no exercise for this common condition.

METHODS: The PubMed, Embase/MEDLINE, and Cochrane Central Register of Controlled Trials databases, from inception to January 9, 2014, were searched for randomized controlled trials comparing the use of quadriceps-strengthening exercises to interventions consisting of advice/information or a placebo. Outcomes of interest were pain measures and function, as measured with self-report questionnaires. The methodological quality of the randomized controlled trials was assessed with the Physiotherapy Evidence Database scale. Results were summarized using a best-evidence synthesis and graphically illustrated using forest plots without meta-analysis.

RESULTS: Seven studies were included in the literature review. These studies reported strong evidence that isolated quadriceps strengthening is more effective in reducing pain and improving function than advice and information alone. In addition, compared to advice and information or placebo, there was strong evidence that quadriceps-strengthening exercises combined with other interventions may be more effective in reducing pain immediately postintervention and after 12 months, but not in improving function.

CONCLUSION: The literature provides strong evidence for the use of quadriceps-strengthening exercises, with or without other interventions, for the treatment of patellofemoral pain syndrome.

LEVEL OF EVIDENCE: Therapy, level 1a–.
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Patellofemoral pain syndrome (PFPS) is one of the most commonly reported injuries in sports medicine.[10,11,38] PFPS is characterized by diffuse retropatellar and peripatellar pain that is aggravated with squatting, prolonged sitting, and stair activities, and is diagnosed in the absence of other pathologies, such as patellar tendinopathy, chondral defects, or patellofemoral osteoarthritis.[12,25,39] Although quadriceps muscle–strengthening exercises are often included as part of the intervention for PFPS,[7,16] the most recent literature review, published in 2003 by Heintjes et al,[16] concluded that there was little evidence to support exercises as an intervention. However, this conclusion was based on the results of only 2 randomized controlled trials (RCTs) and 1 clinically controlled trial.[16]

Since the review by Heintjes et al,[16] a number of studies investigating the effectiveness of quadriceps strengthening for the treatment of PFPS have been published. Therefore, an updated thorough review of the literature on the clinical effectiveness of quadriceps-strengthening exercises appears warranted. The aim of this systematic review was to evaluate and summarize the evidence for therapist-guided quadriceps muscle–strengthening exercises (alone or combined with other interventions) as a treatment for PFPS when compared to advice and information or a placebo treatment.

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METHODS

Search Strategy

A search of the PubMed, Embase/MEDLINE, and Cochrane Central Register of Controlled Trials databases from the date of inception to January 9, 2014 was conducted. Based on the work by Glanville et al,[15] the terms *patellofemoral pain syndrome*, *physical therapy*, *exercise*, and their synonyms and similar terms were used in combination with a Cochrane search filter to maximize sensitivity and precision in identifying RCTs (**APPENDIX A**, available online).[19]

Study Selection

All search records were initially screened, based on the title and abstract. The full text of the retained articles was then screened to determine whether the articles met the inclusion criteria. Finally, the reference sections of the full-text articles were searched to determine if there were other relevant articles that had not been identified through the search. A flow chart of the search and selection process is provided in **FIGURE 1**.

Inclusion and Exclusion Criteria

Only full-text articles of RCTs written in English and Dutch were included in the review. To be included, studies had to report on the clinical outcomes of therapist-guided quadriceps-strengthening exercises, used alone or in combination with other interventions, compared to advice and information or a placebo, for the treatment of individuals with PFPS. PFPS was defined as "diffuse retropatellar and peripatellar pain in the absence of other pathologies."[12,25,39] The exercises used in these studies aimed to enhance quadriceps strength.[27] Studies were included if they reported pain level and/or function, assessed with self-report questionnaires, as outcome measures.

Data Extraction

The first author extracted the following information from each of the selected studies: author names, publication year, characteristics of the study population (number of participants and age, sex, and duration of symptoms), description of the interventions, measurement outcomes for pain and function, follow-up duration, and statistical results (mean difference and 95% confidence interval, *P* value, and effect size).

The studies included in this review were divided into 2 groups. In the first group of studies were RCTs that compared quadriceps-strengthening exercises to advice and information. In the second group were studies that compared quadriceps-strengthening exercises combined with other interventions to the use of advice and information or a placebo treatment.

Quality Assessment

The methodological quality of the studies was assessed with the Physiotherapy Evidence Database (PEDro) scale, a critical appraisal tool for physiotherapy experimental studies.[26] The PEDro scale consists of 11 items and is based on the Delphi list developed by Verhagen et al.[37]

The reliability of scoring the methodological quality of articles using the PEDro scale has been shown to be fair to good in 1 study,[21] with an intraclass correlation coefficient of 0.68, and excellent in another study,[13] with an intraclass correlation coefficient of 0.91. For this review, the classification proposed by the Evidence-Based Review of Stroke Rehabilitation was used.[21,32] Studies scoring 9 or 10 points were considered to be of excellent methodological quality, and studies with scores ranging from 6 to 8 points were of good methodological quality, studies scoring 4 or 5 points were of fair methodological quality. Studies that scored below 4 points were of poor quality. In this classification, scoring did not include the first item on the PEDro scale, so the total PEDro score

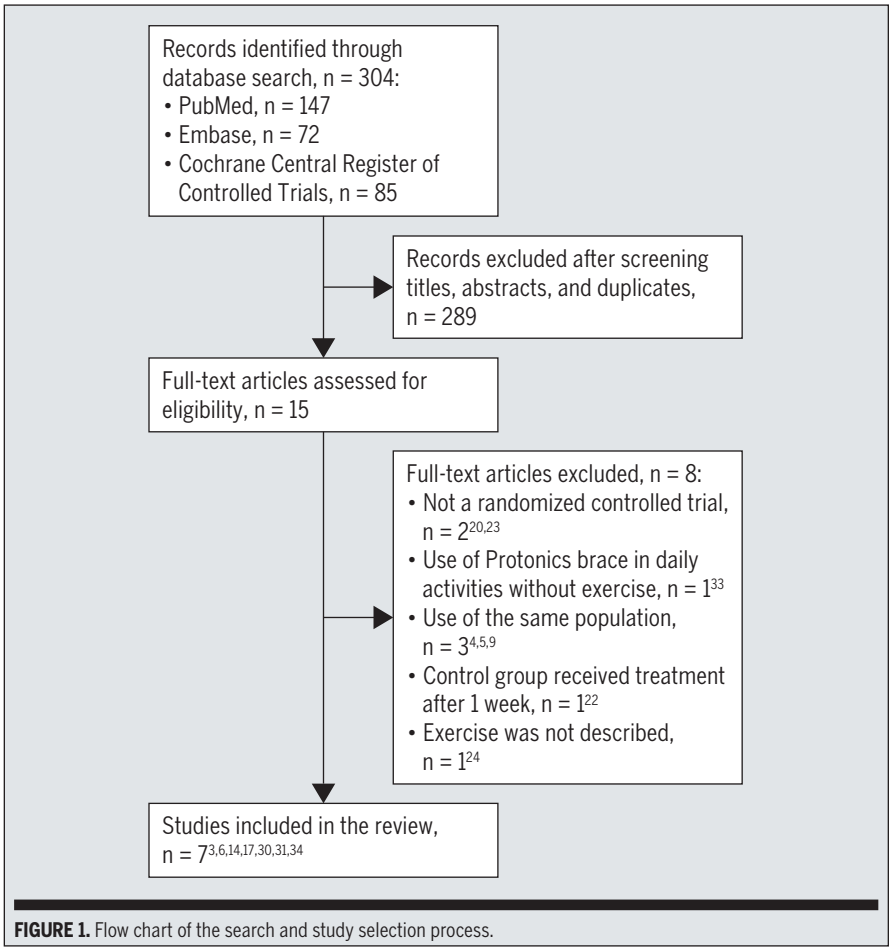


FIGURE 1. Flow chart of the search and study selection process.

TABLE 1 Data for the Studies Included in the Literature Review

Quadriceps-Strengthening Exercises

Study	Population	Intervention Group	Comparison Group	Outcome Measures and Follow-up	Results*
Fukuda et al[14]	70 sedentary females with PFPS; age range, 20-40 y; duration of symptoms, not reported	4 wk, 3 sessions per wk. Exercises: iliopsoas strengthening; seated knee extension; leg press; squatting; stretching of hamstrings, ankle plantar flexors, quadriceps, and iliotibial band	Instructed to maintain daily activities	Pain: 11-point NPRS during ascending stairs and descending stairs Function: LEFS, AKPS Follow-up: immediately postintervention at 4 wk	Pain Ascending stairs change score: IG, −1.5 ± 1.6; CG, 0.1 ± 1.1. Difference in change score‡: IG versus CG, −1.6 (−2.4, −0.8); *P*<.05 Descending stairs change score: IG, −1.0 ± 2.2; CG, −0.3 ± 1.5. Difference in change score‡: IG versus CG, −0.7 (−1.9, 0.5); *P*>.05 Function LEFS change score: IG, 10.0 ± 6.5; CG, 2.4 ± 7.5. Difference in change score§: IG versus CG, 7.6 (3.2, 12.0); *P*<.05 AKPS change score: IG, 10.2 ± 11.6; CG, 0.7 ± 9.9. Difference in change score§: IG versus CG, 9.5 (2.9, 16.1); *P*<.05
Herrington and Al-Sherhi[17]	45 males with PFPS, anterior knee pain, or patellar maltracking; mean ± SD age, 26.9 ± 5.6 y (range, 18-35 y)	6 wk, 3 sessions per wk. Group 1, knee extension exercises; group 2, seated leg press exercises. Both groups: advice as given to the comparison group, warming up on a cycle ergometer	Advice to avoid sport or other pain-provoking activities, but to continue their standard army duties	Pain: VAS, stepping up and down 25-cm step, knee extension strength testing Function: modified Kujala questionnaire Follow-up: immediately postintervention at 8 wk	Pain Difference in postintervention scores, stepping up and down: IGs lower than CG.‡ IG1 versus CG, *P* = .004; IG2 versus CG, *P*<.001. Knee extension strength testing: IGs lower than CG.‡ IG1 versus CG, *P* = .015; IG2 versus CG, *P* = .005 Function Difference in postintervention scores: both IGs had a higher score than the CG (*P*<.001)§
Song et al[30]	89 participants with PFPS. Mean age, 41 y; 69 males, 20 females; mean duration of symptoms, 35.9 mo	8 wk, 3 sessions per wk. Group 1, hip adduction combined with leg press exercise; group 2, leg press exercise. Both groups: hot pack; stretching quadriceps, hamstrings, iliotibial band, and calf; cold pack	Health education material regarding PFP; advice not to perform any exercise program or intervention	Pain: VAS, worst pain previous week Function: Lysholm scale Follow-up: immediately postintervention at 8 wk	Pain Change score: IG1, −2.18 (−3.17. −1.19); IG2, −2.58 (−3.56, −1.61); CG, −0.18 (−1.16, 0.80). Difference in change score‡: IG1 versus CG, −2.19 (−3.44, −0.93); *P* = .001; ES, 0.78; IG2 versus CG, −2.54 (−3.79, −1.30); *P*<.005; ES, 0.92 Function Change score: IG1, 10.93 (7.27, 14.59); IG2, 10.73 (7.13, 14.33); CG, 0.67 (−2.93, 4.27). Difference in change score§: IG1 versus CG, 9.99 (4.81, 15.17); *P*<.005; ES, 1.12; IG2 versus CG, 1.73 (5.60, 15.87); *P*<.005; ES, 1.01

Table continues on page 394.

was the sum of items 2 to 11.[32] All included articles were also independently assessed by a second reviewer (H.F.A.M.), and disagreements with the primary author (L.K.) were discussed and resolved by consensus.

Data Analysis

A best-evidence synthesis was completed by rating the articles using the levels of evidence described by van Tulder et al.[36] To classify the RCTs within the levels of evidence, the classification of Van Peppen et al[35] was used (**APPENDIX B**, available online). The evidence was divided into 5 levels: strong, moderate, limited, indicative findings, and no or insufficient evidence. The results were presented in forest plots, which consisted of the standardized effect size (standard mean difference) calculated from the within-group change score, standard deviation, and the number of participants of each group, using the program RevMan 5.2 (The Nordic Cochrane Centre, Copenhagen, Denmark). Meta-analysis was not warranted due to the heterogeneity of the studies.

RESULTS

Search Results

The literature search identified 304 potentially relevant articles. After excluding 289 articles based on

TABLE 1 Data for the Studies Included in the Literature Review (continued)

Quadriceps-Strengthening Exercises Combined With Other Interventions

Study	Population	Intervention Group	Comparison Group	Outcome Measures and Follow-up	Results*
Clark et al[3]	81 participants with AKP: 45 males, 36 females; mean age, 27.9 y (range, 15-40 y). Duration of symptoms: less than 3 mo, n = 3; 3 to 6 mo, n = 6; 6 to 12 mo, n = 12; greater than 12 mo, n = 60	3 mo, 6 sessions; daily exercises at home. Group 1, exercise and taping and education; group 2, exercise and education. Exercises: squats against the wall; sit-to-stand; proprioceptive balance work; gluteus medius and maximus; progressive step-down exercises; stretching of the hamstrings, iliotibial band, quadriceps, and gastrocnemius	Group 1: taping and education; group 2, education. Education: information and advice about nature of AKP, anatomy of PF joint, causes of AKP, footwear and sport activities, stress relaxation techniques, ice and massage, pain-controlling drugs, diet and weight, prognosis and self-help	Pain: VAS, climbing stairs and walking on a flat surface Function: WOMAC lower-limb function score Follow-up: immediately postintervention at 3 mo and 12 mo	Pain 3 mo, change score: IG1 and IG2, −34.4 ± 41.6; CG1 and CG2, −26.8 ± 43.8. Difference in change scores‡: IG1 and IG2 versus CG1 and CG2, −7.6 (−28, 12.9); *P* = .46. 12 mo, difference in change scores‡: IG1 and IG2 versus CG1 and CG2, pain exercise was lower than no exercise, *P* = .03 Function 3 mo, change score: IG1 and IG2, −11.7 ± 12.4; CG1 and CG2, −13.4 ± 14.2. Difference in change scores§: IG1 and IG2 versus CG1 and CG2, 1.7 (−4.7, 8.1); *P* = .6. 12 mo, difference in change scores§: IG1 and IG2 versus CG1 and CG2, no significant difference
Crossley et al[6]	71 participants with PFPS: 25 males, 46 females; mean age, 27.5 y (range, 12-40 y)	6 wk, 1 session per wk: patellar taping, retraining VMO, gluteal muscle strengthening exercises, stretching of soft tissue structures, home exercise	Placebo taping, sham ultrasound, light application of non-therapeutic gel	Pain: VAS, worst pain in previous week, usual pain in previous week Function: AKPS, FIQ Follow-up: immediately postintervention at 6 wk	Pain Worst pain, preintervention and postintervention scores: IG preintervention, 7.0 ± 1.5; IG postintervention, 3.0 ± 2.0; CG preintervention, 7.0 ± 1.5; CG postintervention, 5.0 ± 2.5. Difference in change scores§: CG versus IG, 2.0 (1.0, 3.5); *P*<.05; ES, 0.80. Usual pain: preintervention and postintervention scores: IG preintervention, 4.5 ± 1.0; IG postintervention, 1.0 ± 1.5; CG preintervention, 4.5 ± 1.0; CG postintervention, 2.5 ± 2.0. Difference in change scores§: CG versus IG, 1.5 (0.5, 2.5); *P*<.05; ES, 0.75. Function AKPS: preintervention and postintervention scores: IG preintervention, 68 ± 7; IG postintervention, 86 ± 9; CG preintervention, 69 ± 9; CG postintervention, 78 ± 12. Difference in change scores§: CG versus IG, −10 (−14, −5); *P*<.05; ES, 0.91. FIQ: preintervention and postintervention scores: IG preintervention, 9 ± 2; IG postintervention, 13 ± 3; CG preintervention, 9 ± 2; CG postintervention, 11 ± 3. Difference in change scores§: CG versus IG, −1 (−3, 0); *P*>.05; ES, 0.33

Table continues on page 395.

titles and abstracts, 15 articles remained. Eight studies were excluded after assessing the full text of the articles.[4,5,9,20,22-24,33] Among these 8 studies, 2 were not RCTs,[20,23] 3 articles[4,5,9] provided data on the same population as the original article,[6] 1 article[33] assessed the use of a Protonics brace without including exercises, in 1 article the control group received treatment after 1 week,[22] and the remaining article did not describe the exercise performed in the study.[24] Cross-referencing revealed no additional relevant articles, for a total of 7 studies[3,6,14,17,30,31,34] included in this review.

TABLE 1 presents the characteristics of the 7 studies included in the review. There were 3 studies[14,17,30] that compared quadriceps-strengthening exercises to advice and information. Five studies[3,6,14,31,34] compared quadriceps-strengthening exercises combined with other interventions to advice and information or placebo. The study by Fukuda et al[14] included

TABLE 1 Data for the Studies Included in the Literature Review (continued)

Quadriceps-Strengthening Exercises Combined With Other Interventions

Study	Population	Intervention Group	Comparison Group	Outcome Measures and Follow-up	Results*
Fukuda et al[14]	70 sedentary females with PFPS: age range, 20-40 y; duration of symptoms, not reported	4 wk, 3 sessions per wk. Knee and hip exercises: iliopsoas strengthening; seated knee extension; leg press; squatting; hip abduction; hip external rotation; side-stepping; knee exercises; stretching of hamstrings, ankle plantar flexors, quadriceps, iliotibial band	Instructed to maintain daily activities	Pain: 11-point NPRS during ascending stairs and descending stairs Function: LEFS, AKPS Follow-up: immediately postintervention at 4 wk	Pain Ascending stairs change score: IG, −2.2 ± 2.3; CG, 0.1 ± 1.1. Difference in change scores‡: IG versus CG, −2.3 (−3.4, −1.2); *P*<.05. Descending stairs change score: IG, −2.6 ± 2.3; CG, −0.3 ± 1.5. Difference in change scores‡: IG versus CG, −2.3 (−3.5, −1.1); *P*<.05 Function LEFS change score: IG, 16.6 ± 16.7; CG, 2.4 ± 7.5. Difference in change scores§: IG versus CG, 14.2 (6.4, 22.0); *P*<.05. AKPS change score: IG, 15.0 ± 12.8; CG, 0.7 ± 9.9. Difference in change scores§: IG versus CG, 14.3 (7.4, 21.2); *P*<.01
Syme et al[31]	69 participants with PFPS: 28 males, 41 females; mean age, 28.2 y; mean duration of symptoms, 48.4 mo	8 wk, 2 sessions per wk. Group 1: selectively retraining the VMO; McConnell approach; group 2: general strengthening of the quadriceps. Both (when necessary): correct lower-limb alignment; tape for pain relief; retrain the gluteus medius muscle; stretching of the quadriceps, iliotibial band, gastrocnemius/soleus, and anterior hip structures; patella mobilization combined with deep friction massage	Advice to refrain from undertaking any forms of exercise programs	Pain: NRS-101: average pain in previous month, MGQ Function: modified FIQ Follow-up: immediately postintervention at 8 wk	Pain NRS-101: preintervention and postintervention scores: IG1 preintervention, 47.7 ± 29.6; IG1 postintervention, 21.4 ± 24.7; IG2 preintervention, 51.3 ± 29.4; IG2 postintervention, 28.1 ± 28.5; CG preintervention, 59.6 ± 21.8; CG postintervention, 49.3 ± 22.5. Difference in postintervention scores‡: IG1 versus CG, −28.0 (−45.9, −1.0); *P*<.001; ES, −1.17 (−1.80, −0.55); IG2 versus CG, −21.2 (−39.1, −3.3); *P* = .008; ES, −0.89 (−1.49, −0.28). MGQ: preintervention and postintervention scores: IG1 preintervention, 17.5 ± 6.1; IG1 postintervention, 9.0 ± 9.0; IG2 preintervention, 20.1 ± 8.8; IG2 postintervention, 7 ± 12.0; CG preintervention, 21.0 ± 9.4; CG postintervention, 17.0 ± 14.0. Difference in postintervention scores‡: IG1 versus CG, −6.0 (−11.0, −1.0); *P* = .014; ES, −0.8 (−1.42, −0.21); IG2 versus CG, −8.0 (−14.0, −4.0); *P* = .003; ES, −1.03 (−1.65, −0.42) Function Preintervention and postintervention scores: IG1 preintervention, 33.0 ± 13.2; IG1 postintervention, 25.0 ± 30.0; IG2 preintervention, 34.8 ± 17.9; IG2 postintervention, 10.0 ± 35.0; CG preintervention, 33.0 ± 15.3; CG postintervention, 30.0 ± 25.0. Difference in postintervention scores‡: no significant differences between 3 groups, *P* = .070. IG1 versus CG, −10.0 (−20.0, 0.0); ES, −0.58 (−1.17, 0.01); IG2 versus CG, −15.0 (−25.0, 0.0); ES, −0.62 (−1.22, −0.03)

Table continues on page 396.

2 intervention groups and was therefore included in both sets of comparisons.

Isolated Quadriceps Strengthening

The 3 studies[14,17,30] that compared quadriceps strengthening to advice and information included a total of 204 par-

TABLE 1 Data for the Studies Included in the Literature Review (continued)

Quadriceps-Strengthening Exercises Combined With Other Interventions

Study	Population	Intervention Group	Comparison Group	Outcome Measures and Follow-up	Results*
van Linschoten et al[34]	131 participants with PFPS: mean ± SD age, 24 ± 8.2 y; 47 males, 84 females; duration of symptoms: 2-6 mo, 89; 6-24 mo, 42	6 wk, 9 sessions: warming up on a cycle ergometer; static and dynamic exercises for the quadriceps, hip adductor, and gluteal muscles; balance exercises; flexibility exercises for major thigh muscles; information and advice as given to the CG	Information and advice about PFPS and its positive prognosis; advice to refrain from all sports activities that provoke pain; advice to use simple analgesic when pain was severe; advice to find alternative ways to maintain fitness; instructions for daily isometric quadriceps contractions	Pain: NRS, pain at rest, pain with activity Function: Kujala PF scale Follow-up: immediately postintervention at 3 mo and 12 mo	Pain 3 mo, pain at rest: preintervention and postintervention scores: IG preintervention, 4.14 ± 2.3; IG postintervention, 2.30 ± 2.5; CG preintervention, 4.03 ± 2.3; CG postintervention, 3.22 ± 2.8. Difference in postintervention scores‡: IG versus CG, −1.07 (−1.92, −0.22); *P* = .01; ES, 0.56. 3 mo, pain with activity: preintervention and postintervention scores: IG preintervention, 6.32 ± 2.2; IG postintervention, 3.81 ± 2.9; CG preintervention, 5.97 ± 2.3; CG postintervention, 4.60 ± 3.0. Difference in postintervention scores‡: IG versus CG, −1.00 (−1.91, −0.08); *P* = .03; ES, 0.54. 12 mo, pain at rest: preintervention and postintervention scores: IG preintervention, 4.14 ± 2.3; IG postintervention, 1.43 ± 2.2; CG preintervention, 4.03 ± 2.3; CG postintervention, 2.61 ± 2.9. Difference in postintervention scores‡: IG versus CG, −1.29 (−2.16, −0.42); *P*<.01; ES, 0.47. 12 mo, pain with activity: preintervention and postintervention scores: IG preintervention, 6.32 ± 2.2; IG postintervention, 2.57 ± 2.9; CG preintervention, 5.97 ± 2.3; CG postintervention, 3.54 ± 3.38. Difference in postintervention scores‡: IG versus CG, −1.19 (−2.22, −0.16); *P* = .02; ES, 0.45 Function 3 mo: preintervention and postintervention scores: IG preintervention, 64.4 ± 13.9; postintervention, 78.8 ± 15.5; CG preintervention, 65.9 ± 15.2; postintervention, 74.9 ± 17.6. Difference in postintervention scores§: IG versus CG, 4.92 (0.14, 9.72); *P* = .04; ES, 0.37. 12 mo: preintervention and postintervention scores: IG preintervention, 64.4 ± 13.9; postintervention, 83.2 ± 14.8; CG preintervention, 65.9 ± 15.2; postintervention, 79.8 ± 17.5. Difference in postintervention scores§: IG versus CG, 4.52 (−0.73, 9.76); *P* = .09

Abbreviations: AKP, anterior knee pain; AKPS, Anterior Knee Pain Scale; CG, comparison group; ES, effect size; FIQ, Functional Index Questionnaire; IG, intervention group; LEFS, Lower Extremity Functional Scale; MGQ, McGill Pain Questionnaire; NPRS, numeric pain rating scale; NRS, numeric rating scale; PF, patellofemoral; PFP, patellofemoral pain; PFPS, patellofemoral pain syndrome; VAS, visual analog scale; VMO, vastus medialis obliquus; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

**Values in parentheses are 95% confidence interval.*

†Only P values were obtained from text; other information was obtained from figures.

‡Negative score is in favor of the intervention group.

§Positive score is in favor of the intervention group.

ticipants (114 men and 90 women). The mean age of the participants ranged from 26.9 years[17] to 41 years.[30] The participants in the study by Song et al[30] had a mean duration of symptoms of 35.9 months.

Intervention The duration of the in-

TABLE 2 Methodological Quality Assessment*

	2	3	4	5	6	7	8	9	10	11	Total	1
Quadriceps-Strengthening Exercises												
Fukuda et al[14]	+	+	+	–	–	+	+	+	+	+	8	+
Herrington and Al-Sherhi[17]	+	+	+	–	–	+	+	+	+	+	8	+
Song et al[30]	+	+	+	–	–	+	+	+	+	+	8	+
Quadriceps-Strengthening Exercises Combined With Other Interventions												
Clark et al[3]	+	+	+	–	–	+	+	+	+	+	8	+
Crossley et al[6]	+	+	+	+	–	+	+	+	+	+	9	+
Fukuda et al[14]	+	+	+	–	–	+	+	+	+	+	8	+
Syme et al[31]	+	+	+	–	–	+	+	+	+	+	8	+
van Linschoten et al[34]	+	+	+	–	–	–	+	+	+	+	7	+

**The methodological quality was assessed with the Physiotherapy Evidence Database (PEDro) scale.[26] The PEDro scale consists of 11 items. The total 10-point PEDro score is the sum of items 2 through 11. When a study fulfilled the criteria for an item, it was awarded 1 point (+); when a study did not fulfill the criteria, no point was awarded (–). Item assessment: 1, eligibility criteria; 2, random allocation; 3, concealed allocation; 4, baseline comparability; 5, blinding subjects; 6, blinding therapists; 7, blinding assessors; 8, outcome data greater than 85%; 9, intention to treat; 10, between-group results; 11, point measures/measures of variability; total, 10-point PEDro score.*

tervention ranged from 4 weeks[14] to 8 weeks,[30] with 3 sessions per week for all 3 studies.[14,17,30] In the study by Fukuda et al,[14] the exercise group performed iliopsoas strengthening in a non–weight-bearing position, as well as seated knee extension, leg press, and squatting exercises. In the study by Song et al,[30] both exercise groups performed leg press exercises, with 1 group combining the exercise with hip adduction in an attempt to further activate the vastus medialis obliquus (VMO). In the study by Herrington and Al-Sherhi,[17] one treatment group performed knee extension exercises in a seated position and another treatment group performed leg press exercises.

Outcome Measures The numeric pain rating scale[14] and the visual analog scale (VAS)[17,30] were used to measure pain. Function was measured with the following questionnaires: the Lower Extremity Functional Scale,[14] Anterior Knee Pain Scale (AKPS),[14] Lysholm scale,[30] and modified Kujala questionnaire.[17]

Follow-up Postintervention measures for each study were conducted at the end of the intervention (at 4 weeks,[14] 6 weeks,[17] and 8 weeks[30]).

Quality Assessment The methodological quality of the studies is described in **TABLE 2**. Five items were discussed by the reviewers and resolved by consensus, resulting in a Cohen kappa of 0.85. All 3 studies[14,17,30] were considered to be of good methodological quality.

Data Analysis In all 3 studies,[14,17,30] which included 5 intervention groups, the groups that performed quadriceps-strengthening exercises had less pain ($P<.05$) postintervention than their respective comparison groups, with Fukuda et al[14] and Song et al[30] reporting change scores (difference between preintervention and postintervention scores) consistent with those findings. It should be noted that in the study by Fukuda et al,[14] a greater improvement in pain for the quadriceps-strengthening group was found for ascending stairs, but not for descending stairs (**FIGURE 2**).

Postintervention function scores were significantly higher ($P<.05$) in all 5 of the groups that performed quadriceps-strengthening exercises compared to the comparison groups,[14,17,30] with the change scores reported by Fukuda et al[14] and Song et al[30] being consistent with these results (**FIGURE 3**).

In all 3 studies,[14,17,30] the individuals with PFPS who performed quadriceps-strengthening exercises for a period of 4 to 8 weeks consistently demonstrated significantly less pain and better function immediately postintervention compared to those receiving a comparison intervention of information and advice. There is, therefore, strong evidence that quadriceps strengthening may be more effective than advice and information for lowering pain and improving function immediately postintervention in individuals with PFPS.

Quadriceps Strengthening Combined With Other Interventions

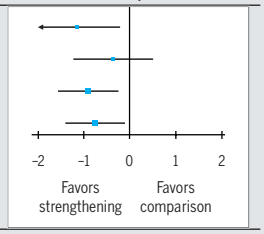
The 5 studies[3,6,14,31,34] that compared quadriceps strengthening combined with other interventions to advice and information included a total of 422 individuals with PFPS (277 women and 145 men). The mean age of the participants was 24 years[34] to 28.2 years.[31] The participants in the study by Syme et al[31] had a mean symptom duration of 48.4 months.

Intervention The duration of the interventions ranged from 4 weeks[14] to 12 weeks,[3] with the frequency of therapy sessions ranging from once every 2 weeks[3] to 3 times a week.[14] In these studies, quadriceps-strengthening exercises were supplemented by hip-strengthening exercises,[3,6,14,31,34] stretching,[3,6,14,31,34] patellar taping,[3,6,31] home exercises,[3,34] education,[34] or soft tissue techniques.[31] In these studies, the comparison groups were provided with advice and information,[3,14,31,34] a placebo treatment,[6] or taping.[3]

Outcome Measures Depending on the study, pain was measured for ascending and descending stairs,[3,14] walking on a flat surface,[3] at rest and with activity,[34] on average,[6,31] and at worst,[6] using a numeric pain rating scale,[14,31,34] the McGill Pain Questionnaire,[31] or a VAS.[3,6] The Lower Extremity Functional Scale,[14] AKPS,[6,14] Kujala patellofemoral scale,[34] modified Functional Index Questionnaire (FIQ),[31]

Pain

Study/Subgroup	Quadriceps Strengthening Mean ± SD	Quadriceps Strengthening Total, n	Comparison Group Mean ± SD	Comparison Group Total, n	Weight	SMD IV, Fixed (95% Confidence Interval)
Fukuda et al[14]*	−1.5 ± 1.6	10	0.1 ± 1.1	12	16.3%	−1.14 (−2.06, −0.22)
Fukuda et al[14]†	−1 ± 2.2	10	−0.3 ± 1.5	11	18.3%	−0.36 (−1.23, 0.50)
Song et al[30]‡	−2.58 ± 2.61	30	−0.18 ± 2.62	15	32.5%	−0.90 (−1.55, −0.25)
Song et al[30]§	−2.18 ± 2.6	29	−0.18 ± 2.62	15	33.0%	−0.75 (−1.40, −0.11)

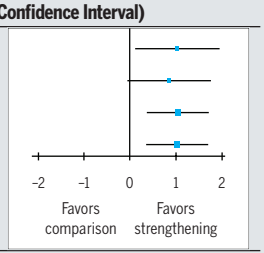


Abbreviation: SMD, standardized mean difference.

FIGURE 2. Quadriceps strengthening versus comparison group: pain. The study by Herrington and Al-Sherhi[17] did not provide the information to be included in the forest plot. *Pain measured with an 11-point numeric pain rating scale during stair ascent. †Pain measured with an 11-point numeric pain rating scale during stair descent. ‡Pain measured with the visual analog scale: worst pain in previous week for the group of hip adduction in combination with leg press exercise. §Pain measured with the visual analog scale: worst pain in previous week for the intervention group with leg press exercise.

Function

Study/Subgroup	Quadriceps Strengthening Mean ± SD	Quadriceps Strengthening Total, n	Comparison Group Mean ± SD	Comparison Group Total, n	Weight	SMD IV, Fixed (95% Confidence Interval)
Fukuda et al[14]*	10 ± 6.5	10	2.4 ± 7.5	12	17.5%	1.03 (0.13, 1.94)
Fukuda et al[14]†	10.2 ± 11.6	10	0.7 ± 9.9	11	17.6%	0.85 (−0.05, 1.75)
Song et al[30]‡	10.93 ± 9.62	29	0.67 ± 9.64	15	32.4%	1.05 (0.38, 1.71)
Song et al[30]§	10.73 ± 9.62	29	0.67 ± 9.64	15	32.6%	1.03 (0.36, 1.69)



Abbreviation: SMD, standardized mean difference.

FIGURE 3. Quadriceps strengthening versus comparison group: function. The study by Herrington and Al-Sherhi[17] did not provide the information to be included in the forest plot. *Function measured with the Lower Extremity Functional Scale. †Function measured with the Anterior Knee Pain Scale. ‡Function measured with the Lysholm scale for the intervention group of hip adduction in combination with leg press exercise. §Function measured with the Lysholm scale for the intervention group with leg press exercise.

the FIQ,[6] and the Western Ontario and McMaster Universities Osteoarthritis Index lower-limb score[3] were used to measure function.

Follow-up All authors provided pain and outcome measures data at the end of their intervention at 4 weeks,[14] 6 weeks,[6] 8 weeks,[31] and 12 weeks.[3,34] In addition, 2 studies had follow-up measurement at 12 months postintervention.[3,34]

Quality Assessment The studies by Fukuda et al,[14] van Linschoten et al,[34] Clark et al,[3] and Syme et al[31] were considered to be of good methodological quality (6-8 points). The study by Crossley et al[6] was of excellent methodological quality (9-10 points). Eligibility criteria were specified in all studies.

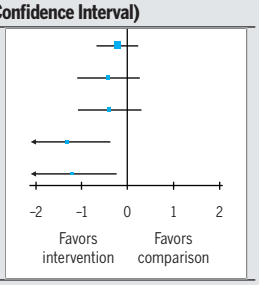
Data Analysis The 5 studies[3,6,14,31,34] included a total of 7 interventions, with 2 studies having 2 separate intervention groups. Individuals in 5 of the 7 intervention groups[3,6,14,31,34] had significantly lower pain scores postintervention compared to those in the respective comparison groups ($P<.05$). Only the study by Clark et al[3] failed to show a difference in pain postintervention between the 2 groups provided with exercises and the 2 groups that did not perform any exercises ($P = .46$). The studies by Fukuda et al,[14] Crossley et al,[6] and Clark et al[3] used change scores to compare treatment groups and the control group (**FIGURE 4**).

Overall, immediately postintervention, in 4 of 5 studies, individuals with PFPS who performed quadriceps-strengthening exercises combined with other interventions demonstrated significantly less pain than those who received education only and/or placebo.[6,14,31,34] Therefore, there is strong evidence that quadriceps strengthening combined with other interventions is more effective in lowering pain immediately postintervention than advice and information or placebo in people with PFPS.

The studies by Fukuda et al[14] and van Linschoten et al,[34] which had 1 intervention group, reported higher function scores immediately postintervention in the intervention group compared to the comparison group ($P<.05$). The study by Crossley et al,[6] which had 1 intervention group, showed inconsistency in outcomes for the 2 functional outcome measures. Function based on the AKPS

Pain

Study/Subgroup	Quadriceps Strengthening Mean ± SD	Quadriceps Strengthening Total, n	Comparison Group Mean ± SD	Comparison Group Total, n	Weight	SMD IV, Fixed (95% Confidence Interval)
Clark et al[3]*	−34.4 ± 41.6	40	−26.8 ± 43.8	41	43.3%	−0.18 (−0.61, 0.26)
Crossley et al[6]†	−4 ± 5.31	18	−2 ± 5.31	18	19.0%	−0.37 (−1.03, 0.29)
Crossley et al[6]‡	−3.5 ± 4.25	18	−2 ± 4.25	17	18.5%	−0.34 (−1.01, 0.32)
Fukuda et al[14]§	−2.2 ± 2.3	11	0.1 ± 1.1	12	10.0%	−1.25 (−2.16, −0.34)
Fukuda et al[14]‖	−2.6 ± 2.3	10	−0.3 ± 1.5	11	9.3%	−1.15 (−2.09, −0.21)

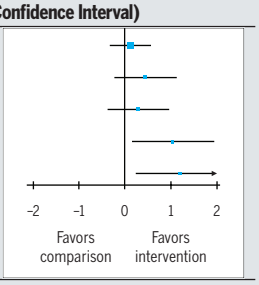


Abbreviation: SMD, standardized mean difference.

FIGURE 4. Quadriceps strengthening combined with other interventions versus comparison group: pain. The studies by Syme et al[31] and van Linschoten et al[34] did not provide the information to be included in the forest plot. *Pain measured with the visual analog scale during climbing stairs and walking on a flat surface. †Worst pain measured with the visual analog scale. ‡Pain measured with the visual analog scale. §Pain measured with the numeric pain rating scale during ascending the stairs. ‖Pain measured with the numeric pain rating scale during descending the stairs.

Function

Study/Subgroup	Quadriceps Strengthening Mean ± SD	Quadriceps Strengthening Total, n	Comparison Group Mean ± SD	Comparison Group Total, n	Weight	SMD IV, Fixed (95% Confidence Interval)
Clark et al[3]*	−11.7 ± 12.4	40	−13.4 ± 14.2	41	43.2%	0.13 (−0.31, 0.56)
Crossley et al[6]†	18 ± 19.04	18	9 ± 19.04	18	18.7%	0.46 (−0.20, 1.13)
Crossley et al[6]‡	4 ± 6.36	18	2 ± 6.36	17	18.4%	0.31 (−0.36, 0.97)
Fukuda et al[14]§	16.6 ± 16.7	11	2.7 ± 7.5	12	10.5%	1.05 (0.17, 1.94)
Fukuda et al[14]†	15.0 ± 12.8	10	0.7 ± 9.9	11	9.2%	1.21 (0.26, 2.16)



Abbreviation: SMD, standardized mean difference.

FIGURE 5. Quadriceps strengthening combined with other interventions versus comparison group: function. The studies by Syme et al[31] and van Linschoten et al[34] did not provide the information to be included in the forest plot. *Function measured with the Western Ontario and McMaster Universities Osteoarthritis Index lower-limb function score. †Function measured with the Anterior Knee Pain Scale. ‡Function measured with the Functional Index Questionnaire. §Function measured with the Lower Extremity Functional Scale.

was significantly improved in the intervention group compared with the comparison group ($P<.05$); however, there was no between-group difference for the FIQ ($P>.05$). The 2 remaining studies[3,31] showed no difference in function scores postintervention ($P>.05$). Again, the studies by Fukuda et al,[14] Crossley et al,[6] and Clark et al[3] used change scores to compare between treatment groups and the control. The forest plot for these studies is presented in **FIGURE 5**.

Based on inconsistent results among these 5 studies, it can be concluded that there is no evidence that quadriceps strengthening combined with other interventions is more effective in improving function than advice and information or a placebo treatment in people with PFPS immediately postintervention.

Long-Term Results van Linschoten et al[34] and Clark et al[3] also assessed pain and function at 12 months postintervention. In both studies,[3,34] pain was significantly lower in the intervention group compared to the comparison group ($P<.05$). Neither study provided sufficient information to make a forest plot.

Significantly less pain was demonstrated for individuals performing quadriceps strengthening in combination with other interventions in 2 studies[3,34] at 12 months. Therefore, there is strong evidence that quadriceps strengthening combined with other interventions is more effective in lowering pain at 12 months than advice and information or a placebo treatment in people with PFPS.

van Linschoten et al[34] and Clark et al[3] reported no significant differences between the intervention and comparison groups for functional outcomes at 12 months ($P>.05$). Neither study provided sufficient information to make a forest plot.

Two studies[3,34] showed no significant differences for function measurements at 12 months for the intervention groups

compared to the control group. Therefore, there is no evidence that quadriceps strengthening combined with other interventions is more effective in improving function at 12 months than advice and information or placebo in people with PFPS.

DISCUSSION

Isolated Quadriceps Strengthening

The level of evidence to support the effectiveness of quadriceps-strengthening exercises compared to advice and information has changed from limited to strong since the last systematic review by Heintjes et al.[16] It is noteworthy that of the 3 studies included in the systematic review of Heintjes et al,[16] only the study by Clark et al[3] fulfilled the criteria for the present review. The study by Timm[33] assessed the use of a Protonics brace in daily activities, which was not considered to be exercise therapy, and the study by McMullen et al[23] was not an RCT. Consistent with the results of this review, the recent systematic review by Lankhorst et al[18] showed that weaker knee extension strength is a risk factor for PFPS.

Quadriceps-strengthening exercises may be divided into non–weight bearing and weight bearing, and general versus selective VMO training. There is no consensus as to which type of exercise is most effective.[1] This is demonstrated by the use of different types of exercise in all studies in this review. In the study by Fukuda et al,[14] the treatment group performed both weight-bearing and non–weight-bearing exercises. In the study by Song et al,[30] both treatment groups performed weight-bearing exercises, with the difference that one group focused on selectively training the VMO.[30] In the study by Herrington and Al-Sherhi,[17] one intervention group performed non–weight-bearing exercises and the other group performed weight-bearing exercises. Based on the results of this review, no specific recommendations can be made as to the type of exercise to use for the treatment of PFPS, as all types appear to be effective. Because in all 3 studies[14,17,30] the frequency of the intervention was 3 times a week, this frequency seems appropriate to use for treatment.

Quadriceps Strengthening Combined With Other Interventions

It is remarkable that when quadriceps strengthening is combined with other interventions, there is no evidence that the treatment is more effective for improving function. As other factors, such as altered lower extremity alignment, may also contribute to PFPS,[39] it would be plausible that including additional interventions would have further improved the effectiveness of care.

The lack of effectiveness in improving function might be explained by the self-reported function outcome measures in the studies that combined exercises with other interventions. The FIQ,[6] the modified FIQ,[31] and the Western Ontario and McMaster Universities Osteoarthritis Index lower-limb score[3] showed no statistical difference between groups in these studies. In contrast, when the Lower Extremity Functional Scale and the AKPS[14] were used, a significantly better functional improvement was recorded for the strengthening intervention groups. For example, in the study by Crossley et al,[6] the AKPS showed a significant difference favoring the intervention group, whereas the FIQ did not. This could be due to the difference in validity and responsiveness of the different outcome measures.

There are few studies comparing different outcome measures. The VAS usual pain, VAS worst pain, and AKPS were more valid and responsive compared to the FIQ and VAS activity in a study that included 71 participants with PFPS in the age range of 12 to 40 years.[8] However, another study of 18 participants with PFPS between 20 and 50 years of age showed that both the FIQ and the VAS worst pain in the previous week were valid for detecting clinical change.[2] The modified FIQ was shown to be valid and reliable in 2 studies with 88 participants with PFPS.[28,29] More research may be required to recommend which outcome measures to use.

Furthermore, only 1 more study with a statistical difference in favor of intervention was needed to have more than 50% of the studies in favor of the intervention group. In the study by Syme et al,[31] the confidence intervals reached zero, indicating that the difference between the intervention group and comparison group almost reached a statistical difference. Reaching statistical difference in this study would have changed the evidence into strong evidence[35] that quadriceps strengthening combined with other interventions is more effective in improving function than advice and information or a placebo treatment in people with PFPS immediately postintervention.

Long-Term Results Only Clark et al[3] and van Linschoten et al[34] assessed pain and function at 12 months postintervention. In both studies, the pain scores were significantly better in the intervention groups; however, there was no difference in function between the intervention group and control group. Of the 2 studies[3,34] that measured long-term effects at 12 months, the study by Clark et al[3] collected questionnaires from only 49 of the 81 participants. Although an intention-to-treat analysis was used, this could have been a source of bias. In these studies, function was measured with the Western Ontario and McMaster Universities Osteoarthritis Index lower-limb function score[3] and the Kujala patellofemoral scale.[34] The validity of these 2 questionnaires needs further study.

It was not an aim of this systematic review to recommend interventions to use in addition to quadriceps strengthening. Furthermore, the variability in the interventions (patellar taping, hip strengthening, balance training, and mobilization of the patella) performed in the studies[3,6,14,31,34] precludes decision making as to which approach is most effective.

The results of this study indicate that quadriceps strengthening should be an important part of treatment for indi-

viduals with PFPS. Data on the effectiveness of adding other interventions are inconclusive. Additional research should be conducted to determine which other interventions to use in addition to quadriceps strengthening in this population.

Limitations

It is possible that the results of the best-evidence synthesis are overrated, because studies with no significant differences are less likely to be published (publication bias).

The authors decided not to perform a meta-analysis due to the heterogeneity of the studies, and, as such, forest plots were included only to visually represent the data. It should be noted that the studies by Fukuda et al[14] (**FIGURE 3**) and Crossley et al[6] (**FIGURES 4** and **5**) reported significant differences between the intervention and comparison groups in their results section, but this difference is not evident in the forest plots. This may be caused by the division of the number of participants, which may not be reported twice in a forest plot.

Only the study by Crossley et al[6] compared treatment with a placebo, and showed statistical differences between the treatment group and placebo group. In the other studies, individuals in the control groups could not be blinded to their group allocation; therefore, a negative placebo effect was possible. The study by Clark et al[3] provided the same number of sessions with a physical therapist for the control group, to control for the guidance of a physical therapist. This was the only study that did not show any statistical differences between the exercise and nonexercise groups, with 60% of the participants in the control group improving sufficiently enough to not require further treatment.[3] Physical therapist guidance included information and advice about the nature of PFPS, anatomy of the patellofemoral joint, causes of PFPS, footwear and sport activities, stress relaxation techniques, ice and massage, pain-control drugs, diet and weight, prognosis, and self-help.[3] The guidance of a physical therapist could therefore be a positive factor in the treatment of PFPS.

Implications for Future Studies

More research about the most appropriate outcome measure to be used in this population is necessary. Psychometric values of several measurement outcomes have been studied[2,8,28,29]; however, no recommendations as to which measurement outcome would be best to use in research and daily practice can be made. Future studies should use the most validated outcome measures to provide stronger evidence for the effectiveness of quadriceps strengthening for the treatment of PFPS. More research on the long-term effects of quadriceps strengthening is necessary. More research should be done to determine which exercises and training modalities are most effective in treating PFPS.

CONCLUSION

There is strong evidence for the effectiveness of isolated quadriceps strengthening, performed at a frequency of 3 times per week, for the treatment of PFPS. Though all types of quadriceps-strengthening exercise (weight bearing and non–weight bearing; general and selective VMO training) were shown to be effective, no recommendations can be made as to which type may be most effective. Studies combining quadriceps strengthening with other interventions provided strong evidence for pain reduction, but not for improvement in function.

KEY POINTS

FINDINGS: In the treatment of people with PFPS, quadriceps strengthening is more effective in lowering pain and improving function postintervention than advice and information alone. Quadriceps strengthening combined with other interventions is more effective in lowering pain directly postintervention and at 12 months.

IMPLICATIONS: In clinical practice, quadriceps-strengthening exercises may be used to lower pain and improve function in patients with PFPS.

CAUTION: Due to the use of different quadriceps-strengthening programs, no recommendations can be made with regard to which exercises are optimal.

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APPENDIX A

PUBMED SEARCH STRATEGY

("Patellofemoral Pain Syndrome" OR "anterior knee pain") AND (Exercise OR "Exercise Therapy" OR rehabilitation OR physiotherapy [Title/Abstract] OR "physical therapy" OR "Physical Education and Training"[Mesh]) AND (randomized controlled trial [pt] OR controlled clinical trial [pt] OR randomized [tiab] OR placebo [tiab] OR clinical trials as topic [mesh: noexp] OR randomly [tiab] OR trial [ti]) NOT (animals[mh] NOT (animals[mh] AND humans [mh]))

APPENDIX B

BEST-EVIDENCE SYNTHESIS CLASSIFICATION SUGGESTED BY VAN PEPPEN ET AL[35]

Strong Evidence

Provided by statistically significant findings in outcome measures in:

- At least 2 high-quality RCTs, with PEDro scores of at least 4 points*

Moderate Evidence

Provided by statistically significant findings in outcome measures in:

- At least 1 high-quality RCT and
- At least 1 low-quality RCT (3 points or less on PEDro scale) or 1 high-quality CCT*

Limited Evidence

Provided by statistically significant findings in outcome measures in:

- At least 1 high-quality RCT or
- At least 2 high-quality CCTs (in the absence of high-quality RCTs)*

Indicative Findings

Provided by statistically significant findings in outcome measures in at least:

- 1 high-quality CCT or low-quality RCT* (in the absence of high-quality RCTs), or
- 2 studies of a nonexperimental nature with sufficient quality (in absence of RCTs and CCTs)*

No Evidence From Trials

- In the case that results of eligible studies do not meet the criteria for 1 of the above stated levels of evidence or
- In the case of conflicting (statistically significant positive and statistically significant negative) results among RCTs and CCTs, or
- In the case of no eligible studies

Abbreviations: CCT, clinically controlled trial; PEDro, Physiotherapy Evidence Database; RCT, randomized controlled trial.

**If the number of studies that show evidence is less than 50% of the total number of studies found within the same category of methodological quality and study design (RCT, CCT, or nonexperimental studies), no evidence will be classified.*