Are adjunct treatments effective in improving pain and function when added to exercise therapy in people with patellofemoral pain? A systematic review with meta-analysis and appraisal of the quality of interventions

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ABSTRACT

Objective To compare the effectiveness of adjunct treatments combined with exercise to exercise alone in people with patellofemoral pain (PFP) and explore the quality of intervention descriptions in randomised controlled trials (RCTs).

Design Systematic review.

Data sources Seven databases were searched in November 2023.

Eligibility RCTs that evaluated the effectiveness of any adjunct treatment combined with exercise to exercise alone on self-reported pain and function in people with PFP.

Results We included 45 RCTs (2023 participants), with 25 RCTs (1050 participants) contributing to meta-analyses. Pooled analysis indicated very low-certainty evidence that neuromuscular electrical stimulation or monopolar dielectric diathermy combined with exercise leads to small and large improvements in self-reported pain when compared with exercise alone (standardised mean difference (95% CI)=−0.27 (−0.53 to −0.02) and −2.58 (−4.59 to −0.57), respectively) in the short-term. For self-reported pain and function, very low-certainty evidence indicates that knee taping, whole-body vibration, electromyographic biofeedback and knee brace combined with exercise do not differ from exercise alone. Interventions are poorly described in most RCTs, adjunct treatments scored on average 14/24 and exercise therapy 12/24 in the Template for Intervention Description and Replication checklist.

Conclusion Neuromuscular electrical stimulation and monopolar dielectric diathermy combined with exercise seem to improve self-reported pain in people with PFP compared with exercise alone. Knee taping, whole-body vibration, electromyographic biofeedback and knee brace do not offer additional benefits to exercise alone. Most interventions are poorly described, which is detrimental to translating research knowledge into clinical practice.

PROSPERO registration number CRD42020197081.

WHAT IS ALREADY KNOW

⇒ Patellofemoral pain is one of the most prevalent conditions in general practice, orthopaedic and sports settings.
⇒ Exercise therapy is widely recognised as a key intervention for patellofemoral pain.
⇒ Clinical experts and international consensus statements recommend adding adjunct interventions (eg, taping) to exercise therapy as best management for patellofemoral pain.

WHAT ARE THE NEW FINDINGS

⇒ Very low-certainty evidence suggests that in the short-term, neuromuscular electrical stimulation or monopolar dielectric diathermy, combined with exercise, improves self-reported pain in people with patellofemoral pain compared to exercise alone, with a small and large effects, respectively.
⇒ Very low-certainty evidence suggests that knee taping, whole-body vibration, electromyographic biofeedback and knee brace may not be effective adjunct treatments.
⇒ Most interventions are poorly described limiting knowledge translation and implementation in clinical practice.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our findings provide level 1 evidence that challenges current clinical practice guidelines and international consensus statements, which recommend that biophysical agents (eg, electrical stimulation, monopolar dielectric diathermy) should not be used in people with patellofemoral pain.

INTRODUCTION

Patellofemoral pain (PFP) is a complex multifactorial condition[1] characterised by pain around or behind the patella during activities that load the patellofemoral joint.[2] PFP is one of the most prevalent conditions in general practice,[3] orthopaedic[4 5] and sports settings, with an annual prevalence of 23% in adults and 29% in adolescents.[6] PFP has a poor prognosis, with only one-third of patients recovering 1-year post-treatment,[7] and 57% still not recovered 8 years post-treatment.[8]

Exercise therapy is recognised as a key treatment for PFP,[2] as a standalone or embedded in multimodal approaches.[1] Clinical guidelines recommend combining exercise therapy with adjunct treatments

such as patellar taping and biofeedback to improve clinical symptoms in this population.[1 9] Previous reviews explored the effect of adjunct treatments in improving PFP.[10–17] However, most reviews are limited to exploring only individual adjunct treatments, and do not explore their effect when combined with exercise therapy—the cornerstone of PFP management and most likely application in clinical practice. These systematic reviews[10–17] were published between 2001 and 2017 (latest update: May 2017). Since then, 30 new randomised clinical trials (RCTs) have explored the effects of adjunct treatments combined with exercise therapy compared with exercise therapy alone. No recent systematic review has synthesised the effects of individual adjunct treatments combined with exercise therapy to guide clinicians in managing PFP.

A review of RCTs summarising the effectiveness of various adjunct treatments added to exercise therapy is needed to inform upcoming PFP clinical practice guidelines and international consensus statements. Additionally, appraising the quality of intervention description in RCTs is crucial to ensure knowledge translation and appropriate implementation in clinical practice. Our systematic review aimed to evaluate the effectiveness of adjunct treatments combined with exercise therapy compared with exercise therapy alone in people with PFP. Our secondary aim was to appraise the quality of the intervention description in PFP RCTs.

METHODS

Our review was guided by the Methodological Expectations of Cochrane Intervention Review standards,[18] Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 checklist[19] and the implementing PRISMA in Exercise, Rehabilitation, Sport medicine and SporTs science.[20] The systematic review protocol was prospectively registered with the International Prospective Register of Systematic Reviews (PROSPERO) on 5 August 2020 (registration number: CRD42020197081) and has been published elsewhere.[21] We did not involve patients or the public when designing our research question.

Deviations from protocol

Detailed deviations from protocol are described in online supplemental file 1. A summary of the changes is described below:

1. Bayesian network meta-analysis was deemed unfeasible.
2. The grey literature was excluded.
3. The Revised Cochrane Risk of Bias 2 tool (RoB 2) for randomised trials was used instead of the Physiotherapy Evidence Database (PEDro) tool.
4. The second aim was changed to assess the quality of intervention descriptions in the RCTs instead of determining the relative efficacy of different types of adjunct treatments plus exercise therapy.

Declaration of equity, diversity and inclusion

The author group consists of four women and two men. Two PhD students, three early career to mid-career researchers and one senior researcher; four members of the author group are affiliated in a university from a non-English speaking low-income and middle-income country, and two members are affiliated in a university from an English speaking high-income country. Our search was inclusive and not restricted to gender, nationality, cultural background, language or age.

Inclusion and exclusion criteria

Trial selection criteria were established a priori using the Population, Intervention, Comparison, Outcome framework.[22] RCTs providing a full-text report were considered for inclusion. Editorials, comments, letters, abstracts, review articles, theses and dissertations were excluded. Trials that met the following criteria were included: (1) participants diagnosed with PFP and its synonyms (eg, anterior knee pain, chondromalacia pattelae) according to the international consensus statement on PFP definition,[2] (2) trials comparing an intervention group (consisting of one adjunct treatment combined with exercise therapy) with a control group (placebo adjunct treatment combined with exercise therapy or exercise therapy alone), (3) trials had to provide the same exercise therapy intervention to the experimental and control groups, with the adjunct intervention being the only difference between them. We considered strength, stretching, endurance, aerobic or resistance training, power and proprioception exercises as exercise therapy interventions, (4) the following interventions were considered adjunct treatments: non-pharmacological interventions including patellofemoral knee orthoses (bracing), visual and electromyographic (EMG) biofeedback, taping, foot orthoses, manual therapy (mobilisation/manipulation), needling therapies (acupuncture and dry needling), behavioural/psychological therapy and biophysical agents such as shortwave, ultrasound, phonophoresis, iontophoresis, neuromuscular electrical stimulation (NMES) and laser therapy and any other complementary therapies, (5) assessed outcome measures of self-reported pain and/or function (eg, Visual Analogue Scale (VAS), Numerical Pain Rating Scale (NPRS), Anterior Knee Pain Scale (AKPS)). Trials exploring knee conditions other than PFP (eg, patellar dislocation, patellar subluxation, patellofemoral osteoarthritis, patellar tendinopathy, Osgood-Schlatter disease, iliotibial band syndrome, Sinding-Larsen-Johansson syndrome or clinical evidence of meniscal injury, ligament instability or joint effusion), or including participants who have undergone surgery, have reported pain from the lumbar spine, hips, ankles or feet, and those with symptomatic osteoarthritis in any lower limb joint were excluded.

Literature search strategy

The search strategy for each of the data sources was developed by two authors (LRS and RFCM) and was published elsewhere.[21] We did not apply any restrictions on settings, language or year of publication. We searched the following databases from inception to November 2023: PubMed (via MEDLINE), Cochrane Central Register of Controlled Trials (CENTRAL), Embase (via Elsevier), PEDro, Cumulated Index to Nursing and Allied Health Literature (CINAHL) (via EBSCO), SPORTDiscus (via EBSCO) and Web of Science (via Clarivate Analytics). As a final step, we screened the reference lists of included trials and relevant systematic reviews to identify potentially relevant trials that could not have been captured by our electronic search—no RCTs were identified. The complete search strategy of all databases is presented in the online supplemental file 2.

Trial selection

First, two authors (LRS and MSS) independently assessed the titles and abstracts of all identified trials to determine potential eligibility. Second, both authors retrieved the potentially eligible full-text trials and independently assessed them against the eligibility criteria. Trials deemed eligible by both authors at this stage were included in the review. Any disagreements at either step were resolved through consensus with a third author (DOS). When the full text of a trial was unavailable, a member of the team (LRS) contacted the authors

(three contact attempts were made, if the authors did not reply, the trial was excluded).

Data extraction

One author (LRS) independently extracted data from included trials into a prepiloted data extraction form. A second author (MSS) independently audited all extracted data for accuracy. Any disagreement was resolved through consultation between the two authors. If the two authors could not agree, a third author (DOS) was available. We made three contact attempts to request data that were either missing or published in graphical form. Where the authors could not be contacted, we used Web Plot Digitizer software (Ankit Rohatgi, California, USA; available at https://automeris. io/WebPlotDigitizer) to extract eligible data from graphical form.[23] Trials that could not be extracted using Web Plot Digitizer software were excluded from the analysis. Information regarding the trials where authors were contacted can be found in the online supplemental file 3. The following data were extracted from eligible trials:

- Trial characteristics: sample size, author and year of publication.
- Participant characteristics: age, sex, population and body mass index (BMI).
- Intervention and comparator characteristics: type of treatment, frequency and duration.
- Outcomes: all available data on self-reported measures of pain and function outcome from each trial's intervention and comparator arm were extracted, including the point estimate and the corresponding measure of variability (SD, p value or 95% CI). Data were extracted for all evaluated timepoints and divided into short-term (<3 months), medium-term (3–12 months) and long-term (>12 months).[24]

Risk of bias assessment

Two authors (LRS and DOS) independently assessed the risk of bias for each trial outcome using the RoB 2 for RCTs.[25] We considered five domains: (1) bias arising from the randomisation process, (2) bias due to deviations from intended interventions, (3) bias due to missing outcome data, (4) bias in measurement of the outcome, (5) bias in selection of the reported result. The authors independently rated each domain as either low risk, some concerns or high risk of bias. A third author (MFP) was available to solve any disagreements.

Quality of intervention descriptions

The Template for Intervention Description and Replication (TIDieR) checklist and guideline[26 27] was applied to evaluate how well both adjunct treatment and exercise-therapy interventions are described in the RCTs. This tool was developed to improve the reporting of interventions across different trial designs.[26] The TIDieR checklist has 12 items and was adapted to the purpose of our review. Each item was assessed on a 3-point Likert scale, with the following categories: not reported (0), partially reported (1) and adequately reported (2), separately for each intervention, adjunct treatment and exercise therapy. The overall score was calculated by summing the score (0, 1 or 2) for each of the 12 items, with a final score ranging from 0 to 24 points.[27] Based on a previous review,[28] we rated the description of the interventions as good (≥21/24), moderate (18–20/24) or poor (≤17/24). The TIDieR checklist was completed by one author (LRS) and audited by a second author (DOS). Any discrepancies were solved by consensus.

Data synthesis and analysis

We pooled data across trials that were sufficiently similar by intervention. After assessing the available evidence, we created the following groups of interventions combined with exercise therapy: (1) NMES (2) monopolar dielectric diathermy, (3) knee taping, (4) whole-body vibration, (5) knee brace and (6) EMG biofeedback. All interventions had exercise therapy alone as the comparator.

Standardised mean differences (SMDs) were calculated using Review Manager statistical software (RevMan V.5, Copenhagen; The Nordic Cochrane Centre, The Cochrane Collaboration, 2014) with 95% CIs to allow for pooling and data comparison of outcomes in individual trials. Where trials reported 95% CIs only, we calculated the SD according to Cochrane guidelines.[18] SMDs were interpreted as: minimal <0.2, small 0.2–0.49, medium 0.50–0.79 and large >0.8. Interpretation of effect estimates and Grading of Recommendations, Assessment, Development and Evaluations (GRADE) findings followed published recommendations.[29] The self-reported function outcome values were inverted to negative to ensure consistent reporting. As a result, when computing SMDs for pain and function outcomes, negative values represent improved pain and function, favouring the adjunct treatment groups. Where there were two or more trials that were sufficiently similar, random-effects meta-analysis with the inverse variance method was performed using Review Manager.[30] The random-effects model was used as heterogeneity was expected in the intervention, comparator and population. Statistical heterogeneity was assessed by visually inspecting forest plots and examining the χ^2 test for heterogeneity. I^2 values of 30%, 50% and 75% were considered moderate, substantial and considerable statistical heterogeneity, respectively.[18 31] Assessment of publication bias was not possible as there were <10 trials in each meta-analysis.[18]

For trials with two or more comparator groups where data pooling was undertaken, we combined groups receiving similar interventions[32 33] to create a single pairwise comparison in order to prevent a unit-of-analysis error as recommended by the Cochrane Handbook.[18] Data from studies that applied taping in areas other than the knee (eg, femur, tibia or foot) were not included in our analyses.

Certainty of evidence

We used the GRADE framework[29 34] to assess the certainty of evidence for each pooled analysis. One author (LRS) used GRADEpro software (McMaster University, 2015, developed by Evidence Prime, available from gradepro.org) to assess the certainty of evidence for each outcome independently. Evidence started as high certainty but was downgraded if there was a concern with the risk of bias, indirectness, inconsistency or imprecision. The GRADE was assessed by one author (LRS) and audited by a second author (DOS). Any discrepancies were solved by consensus. Full details of upgrade and downgrade criteria for all GRADE categories can be found in the online supplemental file 4.

RESULTS

Trial selection characteristics

The PRISMA flow chart for trial selection is outlined in figure 1. We identified 11 106 records through database searches, 5823 titles and abstracts were screened, 111 potential full texts were assessed using eligibility criteria and 45 trials were included in the review. Online supplemental file 5 provides the reasons for the exclusion of full texts. From the 45 trials, 25 were included in the quantitative analysis. Online supplemental file 6 describes the reasons why trials could not be pooled.

Of these 45 trials, 13 (n=590 participants) investigated the effect of biophysical agents,[35–47] 12 (n=426 participants) investigated the effect of taping,[32 33 48–57] 4 (n=144 participants) investigated the effect

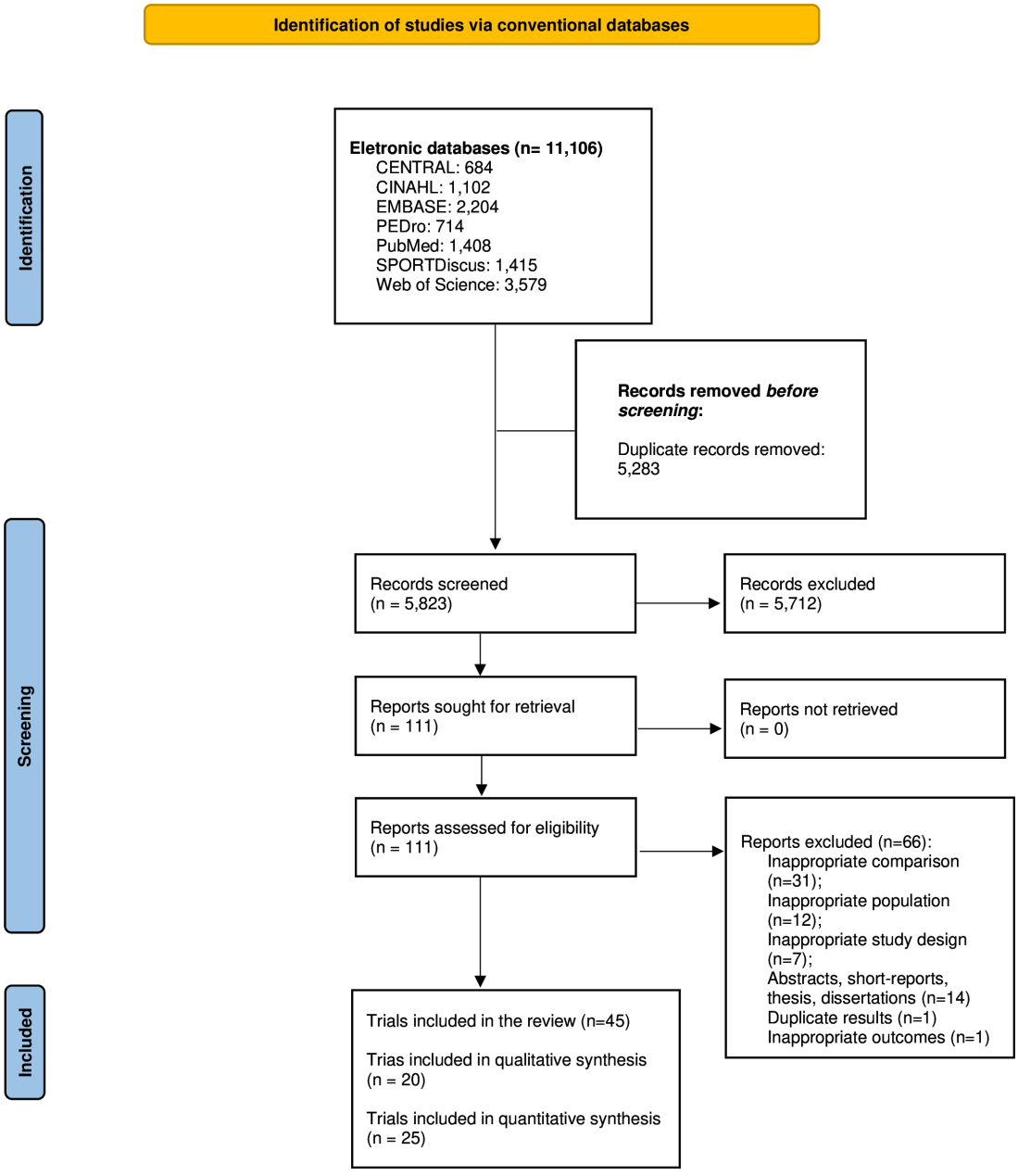


Figure 1 Flow chart.

of whole-body vibration,[58–61] 3 (n=148 participants) investigated the effect of dry needling,[62–64] 3 (n=256 participants) investigated the effect of knee brace,[65–67] 3 (n=115 participants) investigated the effect of manual therapy,[68–70] 2 (n=139 participants) investigated the effect of blood flow restriction,[71 72] 2 (n=86 participants) investigated the effect of EMG biofeedback,[73 74] 1 (n=70 participants) investigated the effect of internal and external attentional focus,[75] 1 (n=29 participants) investigated the effect of mindfulness[76] and 1 (n=20 participants) investigated the effect of foot orthoses.[77] Measurement outcomes included pain evaluated through the VAS,[32 33 35–40 42–47 49 50 52–58 60–62 67 68 71 72 74–77] NPRS,[51 59 63 64 69 70] pain severity scale,[73] numerical analogue scale[65] and verbal pain scale,[66] and function evaluated with the AKPS,[32 33 35 36 40 41 43 44 46 48 49 51 53 58 60–66 69 71 72 75] knee function scale,[67] functional index questionnaire,[55 74] knee outcome survey,[76] lower extremity functional scale,[68 70] Knee Injury and Osteoarthritis Outcome Score—Activities of Daily Living[52] and the Western Ontario and McMaster Universities Osteoarthritis Index.[56] Participants' mean age and BMI ranged from 14 to 63 years and 22–29 kg/m^2, respectively. Mostly, the participants were adults (aged 18–40 years) from the general population,[32 33 35–41 43–48 52–54 56–58 60 62 65–70 72–74] with five trials involving sedentary patients.[49–51 61 71] Additionally, three trials included army recruits,[42 55 64] one trial involved adolescents[77] and four trials included athletes.[59 63 75 76] Characteristics of the 45 trials are provided in online supplemental table 1. The specifics of all interventions and comparators are described using the TIDieR[26] checklist in online supplemental file 7.

Risk of bias

Results from risk of bias can be found in figure 2. We rated 10 outcomes as 'some concerns'[39 41 43 64 72 76] and 67 outcomes as 'high risk of bias'.[32 33 35–38 40 42 44–63 65–71 73–75 77] The risk of bias was largely consistent between the trials and was mostly due to bias arising from measurement of the outcome and selection of the reported result.

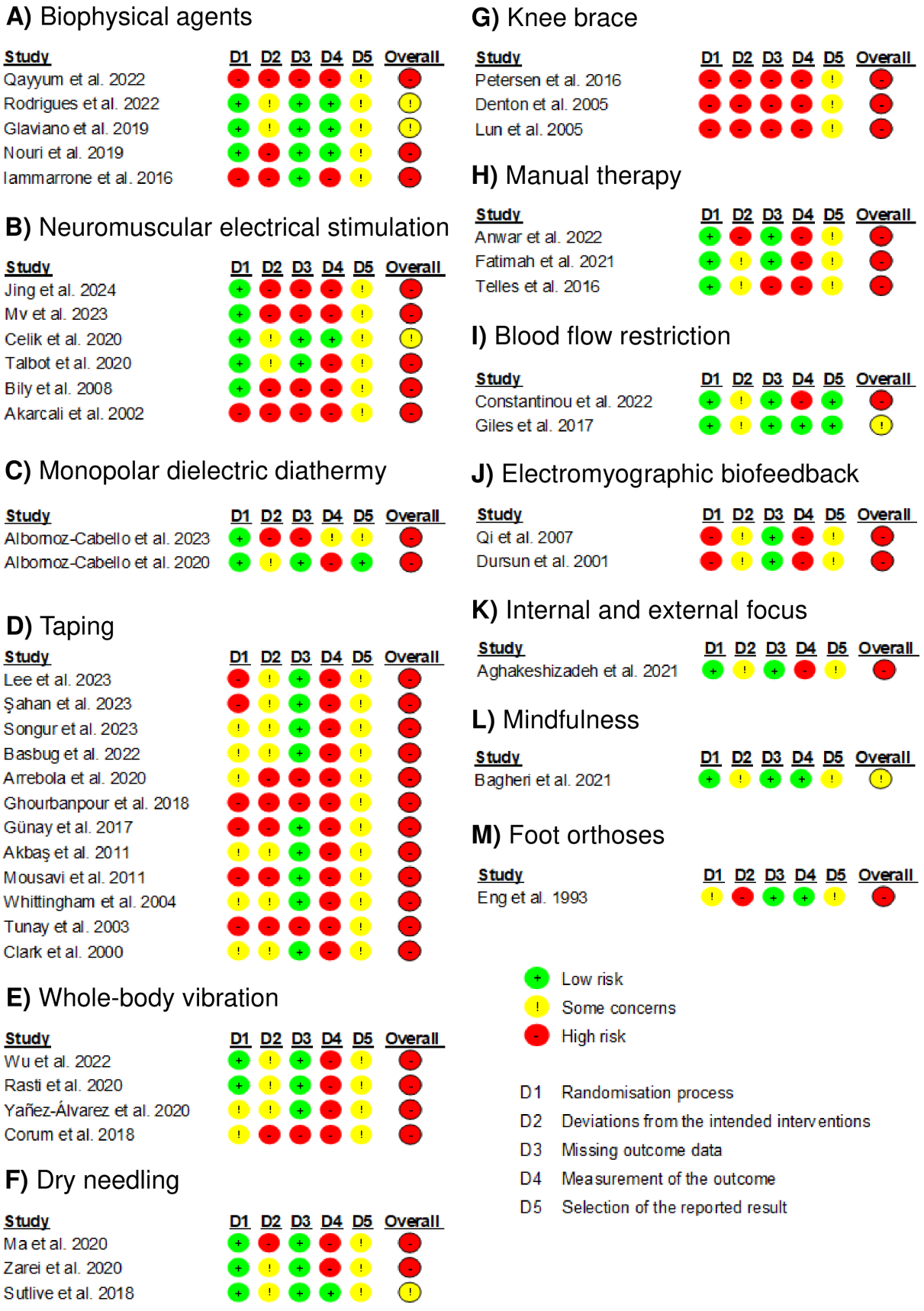


Figure 2 Risk of bias for included trials.

Table 1 Summary of adjunct treatments pooled in the short-term (<3 months)

Adjunct treatment outcomes	SMD (95% CI)	No. of participants (trials)	Certainty of the evidence (GRADE)	Comments
Self-reported pain				
Neuromuscular electrical stimulation	SMD **0.27 lower** (0.53 lower to 0.02 lower)	238 (5)	⊕◯◯◯VERY LOW	Downgrade because of risk of bias within studies, indirectness (outcome measures used, timepoints when outcome assessed and differences between interventions) and imprecision (wide CI)
Monopolar dielectric diathermy	SMD **2.58 lower** (4.59 lower to 0.57 lower)	140 (2)	⊕◯◯◯VERY LOW	Downgrade because of risk of bias within studies, high statistical heterogeneity, indirectness (difference between interventions) and imprecision (wide CI)
Knee taping	SMD 0.17 higher (0.07 lower to 0.41 higher)	276 (8)	⊕◯◯◯VERY LOW	Downgrade because of risk of bias within studies, indirectness (outcome measures used, timepoints when outcome assessed and differences between interventions) and imprecision (wide CI)
Whole-body vibration	SMD 1.10 lower (2.34 lower to 0.14 higher)	144 (4)	⊕◯◯◯VERY LOW	Downgrade because of risk of bias within studies, high statistical heterogeneity, indirectness (difference between interventions) and imprecision (wide CI)
EMG biofeedback	SMD 0.34 higher (0.08 lower to 0.77 higher)	86 (2)	⊕◯◯◯VERY LOW	Downgrade because of risk of bias within studies, indirectness (outcome measures used, timepoints when outcome assessed and differences between interventions) and imprecision (wide CI)
Self-reported function				
Neuromuscular electrical stimulation	SMD 0.44 lower (1.08 lower to 0.20 higher)	154 (4)	⊕◯◯◯VERY LOW	Downgrade because of risk of bias within studies, high statistical heterogeneity, indirectness (outcome measures used, timepoints when outcome assessed and differences between interventions) and imprecision (wide CI)
Monopolar dielectric diathermy	SMD 0.93 lower (2.11 lower to 0.26 higher)	140 (2)	⊕◯◯◯VERY LOW	Downgrade because of risk of bias within studies, high statistical heterogeneity, indirectness (difference between interventions) and imprecision (wide CI)
Knee taping	SMD 0.02 higher (0.22 lower to 0.26 higher)	275 (8)	⊕◯◯◯VERY LOW	Downgrade because of risk of bias within studies, indirectness (outcome measures used, timepoints when outcome assessed and differences between interventions) and imprecision (wide CI)
Whole-body vibration	SMD 0.87 lower (1.80 lower to 0.06 higher)	120 (3)	⊕◯◯◯VERY LOW	Downgrade because of risk of bias within studies, and indirectness (difference between interventions)
Knee brace	SMD 0.18 lower (1.48 lower to 1.13 higher)	100 (2)	⊕◯◯◯VERY LOW	Downgrade because of risk of bias within studies, high statistical heterogeneity, indirectness (difference between interventions) and imprecision (wide CI)

GRADE Working Group grades of evidence:

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.

SMD of <0.2, 0.2–0.49, 0.50–0.79 and >0.8 represents a minimal, small, medium and large effect, respectively.

Significant values are in bold.
EMG, electromyographic; GRADE, Grading of Recommendations, Assessment, Development and Evaluations; SMD, standardise mean difference.

Data synthesis

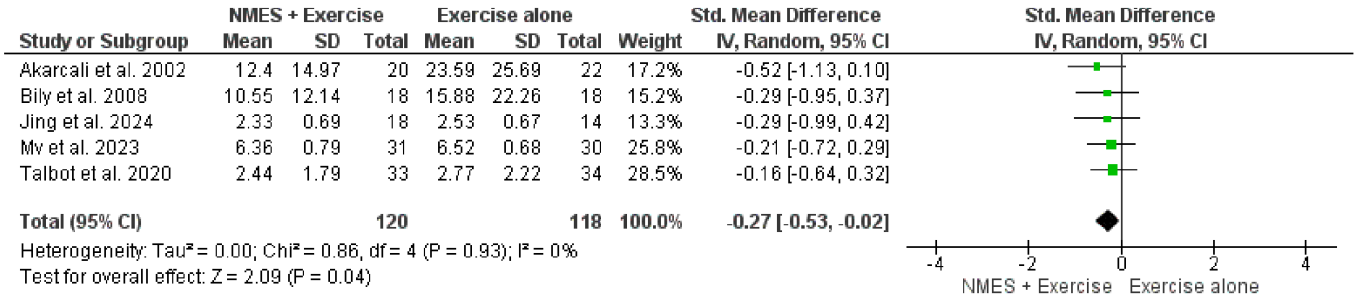
Results from pooled analyses and certainty of the evidence are summarised in table 1. The pooled analyses were performed considering the outcomes evaluated at short-term. Summary GRADE tables for all pooled comparisons are presented in the online supplemental file 4. Results for outcomes in trials ineligible for pooling are presented in the online supplemental file 8, including their SMD, 95% CI and a narrative synthesis.

Biophysical agents

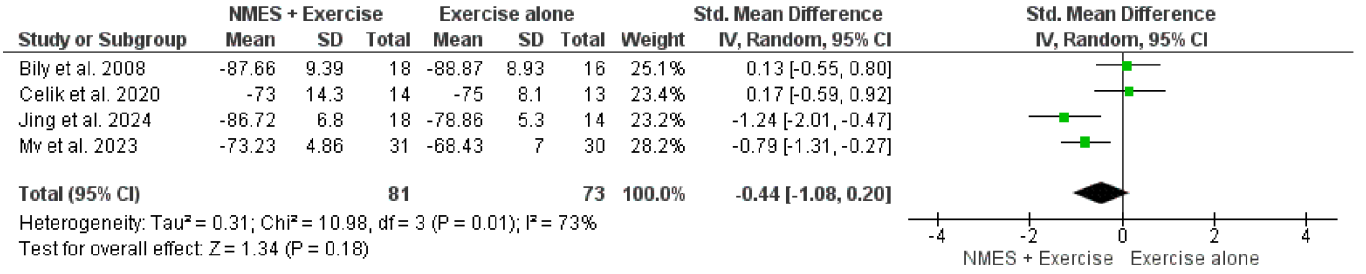
Neuromuscular electrical stimulation

Six trials (n=265 participants) compared electrical muscle stimulation combined with exercise therapy with exercise therapy alone in the short-term.[36 37 41 42 46 47] Data from five trials (n=238 participants) were pooled for analysis,[36 37 42 46 47] and the results indicate there is very low-certainty evidence with low statistical heterogeneity

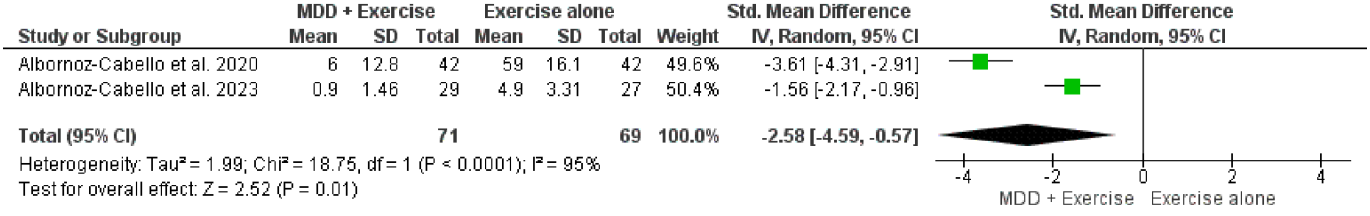
A) Effect of neuromuscular electrical stimulation as adjunct treatment on self-reported pain



B) Effect of neuromuscular electrical stimulation as adjunct treatment on self-reported function



C) Effect of monopolar dielectric diathermy as adjunct treatment on self-reported pain



D) Effect of monopolar dielectric diathermy as adjunct treatment on self-reported function

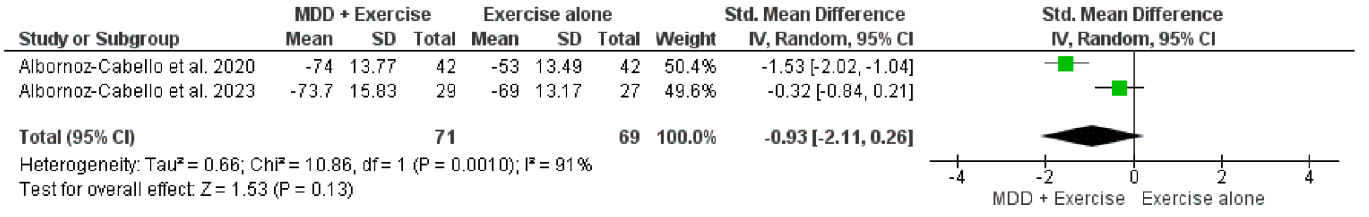


Figure 3 Effects of neuromuscular electrical stimulation combined with exercise (A, B) and monopolar dielectric diathermy combined with exercise therapy (C, D) compared with exercise therapy alone for self-reported pain and function at short-term (IV, inverse variance; MDD, monopolar dielectric diathermy; NMES, neuromuscular electrical stimulation). The self-reported function values were inverted to negative to ensure consistent reporting. All self-reported measures of pain and function were assessed using the Visual Analogue Scale and the Anterior Knee Pain Scale, respectively.

(I^2=0%) to suggest that electrical muscle stimulation combined with exercise therapy leads to small improvement (SMD (95% CI)=−0.27 (−0.53 to −0.02), p=0.04) in self-reported pain when compared with exercise therapy alone (figure 3A). For self-reported function, data from four trials (n=154 participants) were pooled,[36 37 41 46] and the pooled analysis indicates there is very low-certainty evidence with considerable statistical heterogeneity (I^2=73%) to suggest that electrical muscle stimulation combined with exercise therapy is not significantly different from exercise therapy alone (SMD (95% CI)=−0.44 (−1.08 to 0.20), p=0.18) (figure 3B).

Monopolar dielectric diathermy

Data from two trials (n=140 participants) compared monopolar dielectric diathermy combined with exercise therapy with exercise therapy alone in the short-term.[35 40] The pooled analysis indicates there is very low-certainty evidence with considerable statistical heterogeneity (I^2=95%) to suggest that monopolar dielectric diathermy combined with exercise therapy leads to a large improvement (SMD (95% CI)=−2.58 (−4.59 to −0.57), p=0.01) in self-reported pain when compared with exercise therapy alone (figure 3C). For self-reported function, the pooled analysis indicates there is very low-certainty evidence with considerable statistical heterogeneity (I^2=91%) to suggest that monopolar dielectric diathermy is not significantly different from exercise therapy alone (SMD (95% CI)=−0.93 (−2.11 to 0.26), p=0.13) (figure 3D).

Knee taping

Nine trials (n=315 participants) compared knee taping combined with exercise therapy with exercise therapy alone in the short-term.[32 33 48 49 51–53 56 57] Data from eight trials (n=276 participants) were pooled for analysis.[32 33 49 51–53 56 57] Five trials used knee taping for patellar medialisation (three trials with rigid tape and two trials with kinesio tape), while two trials used patellar taping (one trial with rigid tape and one trial with kinesio tape). Additionally, one trial used knee kinesio tape for muscle stimulation. The results indicate there is very low-certainty evidence with low statistical heterogeneity (I^2=0%) to suggest that knee taping combined with exercise therapy is not significantly different from exercise therapy alone in improving self-reported pain (SMD (95% CI)=0.17 (−0.07 to 0.41), p=0.16) (figure 4A). For self-reported function, data from eight trials (n=275 participants) were also pooled.[32 33 48 49 51–53 56] Five trials used knee taping for patellar medialisation (three trials with rigid tape and two trials with kinesio tape), while two trials used kinesio tape for patellar stabilisation and one trial used kinesio tape for muscle stimulation. The pooled analysis indicates there is very low-certainty evidence with low statistical heterogeneity (I^2=0%) to suggest that knee taping combined with exercise therapy is not significantly different from exercise therapy alone (SMD (95% CI)=0.02 (–0.22 to 0.26), p=0.88) (figure 4B). Findings of sensitivity analyses exploring the effect of each taping technique do not differ from the findings of all knee taping techniques combined (online supplemental file 9).

Whole-body vibration

Four trials (n=144 participants) compared whole-body vibration combined with exercise therapy with exercise therapy alone in the short-term.[58–61] The pooled analysis indicates there is very low-certainty evidence with considerable statistical heterogeneity (I^2=91%) to suggest that whole-body vibration combined with exercise therapy is not significantly different from exercise therapy alone in improving self-reported pain (SMD (95% CI)=−1.10 (−2.34 to 0.14), p=0.08) (figure 4C). For self-reported function, data from three trials (n=120 participants) were pooled,[58 60 61] and the pooled analysis indicates there is very low-certainty evidence with considerable statistical heterogeneity (I^2=83%) to suggest that whole-body vibration combined with exercise therapy is not significantly different from exercise therapy alone (SMD (95% CI)=−0.87 (−1.80 to 0.06), p=0.07) (figure 4D).

Knee brace

Two trials (n=100 participants) compared knee brace combined with exercise therapy with exercise therapy alone in the short-term.[66 67] Pooled analysis indicates there is very low-certainty evidence with considerable statistical heterogeneity (I^2=89%) to suggest that knee brace combined with exercise therapy does not differ from exercise therapy alone in improving self-reported function (SMD (95% CI)=−0.18 (−1.48 to 1.13), p=0.79) (figure 5A).

EMG biofeedback

Two trials (n=86 participants) compared EMG biofeedback combined with exercise therapy with exercise therapy alone in the short-term.[73 74] Pooled analysis indicates there is very low-certainty evidence with low statistical heterogeneity (I^2=0%) to suggest that EMG biofeedback combined with exercise therapy does not differ from exercise therapy alone in improving self-reported pain (SMD (95% CI)=0.34 (−0.08 to 0.77), p=0.12) (figure 5B).

Quality of intervention descriptions

The mean quality of intervention descriptions scored using the TIDieR checklist was 14 out of 24 for adjunct treatment descriptions and 12 out of 24 for exercise therapy descriptions, with scores ranging from 1 to 20 points and 2 to 22 points, respectively. A detailed assessment of the quality of the intervention description can be found in online supplemental file 10. From 45 trials, 35 had a poor description of their adjunct treatments,[32 33 35–42 44 47–50 52–59 61–64 66–70 73 74 77] while 10 trials had a moderate description.[43 45 46 51 60 65 71 72 75 76] Regarding exercise therapy descriptions, 39 trials had a poor description,[32 33 35–42 44 45 47–59 61–70 73–75 77] 5 trials had a moderate description[43 46 60 72 76] and 1 trial had a good description.[71] The most prevalent lacking items for adjunct treatments and exercise therapy were items: 10 (45/45 trials for adjunct treatment and 43/45 trials for exercise therapy) (modifications: if the intervention was modified during the course of the study), 11 (39/45 trials for adjunct treatment and 34/45 trials for exercise therapy) (how well planned: if the intervention adherence or fidelity was assessed, how and by whom and if any strategies were used to maintain or improve fidelity) and 12 (40/45 trials for adjunct treatment and 40/45 trials for exercise therapy) (how well: if the intervention adherence or fidelity was assessed, describe the extent to which the intervention was delivered as planned).

DISCUSSION

Summary of findings

We identified 11 adjunct treatment categories; however, pooled analyses were only feasible for 6 adjunct treatments due to the heterogeneity among treatments within these categories. Very low-certainty evidence indicates that, in the short-term, NMES or monopolar dielectric diathermy combined with exercise leads to small and large improvements in self-reported pain compared with exercise alone, respectively. For self-reported pain and function, very low-certainty evidence indicates that knee taping, whole-body vibration, EMG biofeedback and knee brace combined with exercise do not differ from exercise alone in the short-term. Interventions are poorly described in most RCTs, adjunct treatments scored on average 14/24 and exercise therapy 12/24 in the TIDieR checklist.

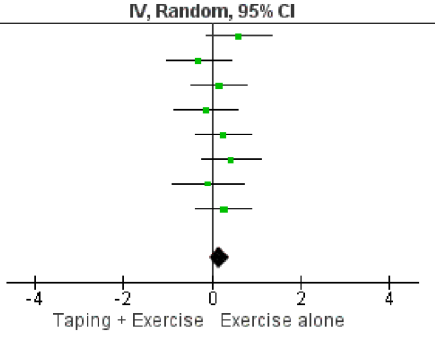
NMES and monopolar dielectric diathermy

Despite providing additional benefits when combined with exercise therapy, neither NMES nor monopolar dielectric diathermy

A) Effect of knee taping as adjunct treatment on self-reported pain

Study or Subgroup	Taping + Exercise Mean	SD	Total	Exercise alone Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Akbaş et al. 2011	1.71	1.67	15	0.81	1.16	16	11.0%	0.61 [-0.11, 1.34]
Arrebola et al. 2020	0.43	0.79	13	1	2.31	16	10.6%	-0.31 [-1.04, 0.43]
Clark et al. 2000	35.9	28.7	20	30	39.9	20	15.0%	0.17 [-0.45, 0.79]
Ghourbanpour et al. 2018	26.77	18.62	15	29.92	27.56	15	11.3%	-0.13 [-0.85, 0.59]
Günay et al. 2017	23.8	14.23	16	20.5	11.4	27	15.0%	0.26 [-0.36, 0.88]
Şahan et al. 2023	2	2.18	14	1.2	1.63	25	13.2%	0.43 [-0.24, 1.09]
Songur et al. 2023	0.8	1.1	12	0.9	1	12	9.0%	-0.09 [-0.89, 0.71]
Tunay et al. 2003	2.7	1.38	20	2.35	1.13	20	14.9%	0.27 [-0.35, 0.89]
Total (95% CI)			**125**			**151**	**100.0%**	**0.17 [-0.07, 0.41]**

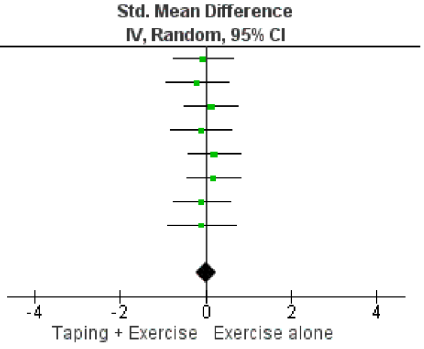
Heterogeneity: Tau² = 0.00; Chi² = 4.90, df = 7 (P = 0.67); I² = 0%
Test for overall effect: Z = 1.41 (P = 0.16)



B) Effect of knee taping as adjunct treatment on self-reported function

Study or Subgroup	Taping + Exercise Mean	SD	Total	Exercise alone Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Akbaş et al. 2011	-82.13	4.91	15	-81.69	9.54	16	11.6%	-0.06 [-0.76, 0.65]
Arrebola et al. 2020	-86.43	12.7	13	-83.7	15.09	16	10.7%	-0.19 [-0.92, 0.55]
Clark et al. 2000	11.5	10.5	20	10	11.8	20	14.9%	0.13 [-0.49, 0.75]
Ghourbanpour et al. 2018	-63.05	23.76	15	-60.62	23.35	15	11.2%	-0.10 [-0.82, 0.62]
Günay et al. 2017	-88.12	5.4	16	-89.15	4.6	27	14.9%	0.21 [-0.41, 0.83]
Lee et al. 2023	-68.3	9.3	20	-69.9	7.4	19	14.5%	0.19 [-0.44, 0.82]
Şahan et al. 2023	-82.21	10.82	14	-81.03	12.76	25	13.4%	-0.10 [-0.75, 0.56]
Songur et al. 2023	-84.3	6.7	12	-83.5	9.1	12	8.9%	-0.10 [-0.90, 0.70]
Total (95% CI)			**125**			**150**	**100.0%**	**0.02 [-0.22, 0.26]**

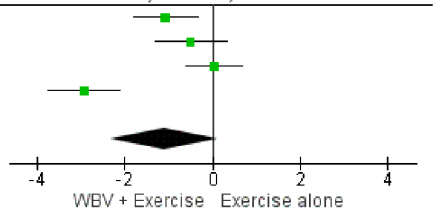
Heterogeneity: Tau² = 0.00; Chi² = 1.40, df = 7 (P = 0.99); I² = 0%
Test for overall effect: Z = 0.15 (P = 0.88)



C) Effect of whole-body vibration as adjunct treatment on self-reported pain

Study or Subgroup	WBV + Exercise Mean	SD	Total	Exercise alone Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Corum et al. 2018	1.5	1.6	18	3.4	1.9	16	25.2%	-1.06 [-1.79, -0.34]
Rasti et al. 2020	3.16	1.19	12	3.83	1.4	12	24.6%	-0.50 [-1.31, 0.32]
Wu et al. 2022	21.5	9.34	18	21.1	9.34	18	25.6%	0.04 [-0.61, 0.70]
Yañez-Álvarez et al. 2020	10	15.4	25	54	14.1	25	24.6%	-2.93 [-3.75, -2.12]
Total (95% CI)			**73**			**71**	**100.0%**	**-1.10 [-2.34, 0.14]**

Heterogeneity: Tau² = 1.44; Chi² = 32.79, df = 3 (P < 0.00001); I² = 91%
Test for overall effect: Z = 1.75 (P = 0.08)



D) Effect of whole-body vibration as adjunct treatment on self-reported function

Study or Subgroup	WBV + Exercise Mean	SD	Total	Exercise alone Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Corum et al. 2018	-87.5	9.2	18	-73.3	10.8	16	31.9%	-1.39 [-2.15, -0.63]
Wu et al. 2022	-86.2	7.67	18	-86.7	7.67	18	33.7%	0.06 [-0.59, 0.72]
Yañez-Álvarez et al. 2020	-71	15.6	25	-52	13	25	34.4%	-1.30 [-1.92, -0.69]
Total (95% CI)			**61**			**59**	**100.0%**	**-0.87 [-1.80, 0.06]**

Heterogeneity: Tau² = 0.56; Chi² = 11.52, df = 2 (P = 0.003); I² = 83%
Test for overall effect: Z = 1.82 (P = 0.07)

Figure 4 Effects of knee taping combined with exercise therapy (A, B) and whole-body vibration (WBV) combined with exercise therapy (C, D) compared with exercise therapy alone for self-reported pain and function at short-term (IV, inverse variance). The self-reported function values were inverted to negative to ensure consistent reporting. Akbaş *et al*[53], Clark *et al*[56], Ghourbanpour *et al*[52], Günay *et al*[33], Şahan *et al*[32], Songur *et al*[49], Tunay *et al*[57], Corum *et al*[61], Wu *et al*[58] and Yañez-Álvarez *et al*[60] assessed the self-reported measure of pain using the Visual Analogue Scale (VAS) while Arrebola *et al*[51] and Rasti *et al*[59] assessed it using the Numerical Pain Rating Scale (NPRS) and Numerical Rating Scale (NRS), respectively. Akbaş *et al*[53], Arrebola *et al*[51], Günay *et al*[33], Lee *et al*[48], Şahan *et al*[32], Songur *et al*[49], Corum *et al*[61], Wu *et al*[58] and Yañez-Álvarez *et al*[60] assessed the self-reported measure of function using the Anterior Knee Pain Scale (AKPS), while Clark *et al*[56] and Ghourbanpour *et al*[52] assessed it using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and the Knee Injury and Osteoarthritis Outcome Score - Activities of Daily Living (KOOS-ADL), respectively.

is recommended by PFP clinical practice guidelines or international consensus statements.[9 78] Our findings should be used to update current recommendations from these documents against biophysical agents for people with PFP. However, caution should be taken when proposing recommendations because the very low-certainty evidence indicates further high-quality RCTs may change our findings.

The NMES trials displayed large variability in the parameters applied. The majority used a 50 Hz pulse frequency[36 37 41 42] and a pulse amplitude ranging from 0 to 99 mA.[36 42 46] Additionally, most employed a pulse duration of 400 µs[36 41 42] and applied intensity close to the maximum tolerable for patients.[36 37 46 47] The lack of consensus in the literature regarding NMES parameters reflects the difficulty in drawing definitive conclusions in our systematic review and in previous reviews evaluating the effects of NMES on patients with PFP[16] and knee osteoarthritis.[79–81]

Only two trials[35 40] evaluating the effectiveness of monopolar dielectric diathermy were included in our review, both from the same research group. Conducting a similar RCT in different geographic locations and settings would be beneficial to improve external validity. Pulsed emission used for monopolar dielectric diathermy varied slightly across trials (ie, 640 kHz[35] and 840 kHz[40]), while the application technique and time were the same (ie, 12 min of dynamic application with a continuous rotation and translational movement on the anterior surface of the knee). To the best of our knowledge, these are the only trials evaluating monopolar dielectric diathermy in people with knee pain, making it challenging to compare our results with other knee conditions or other parameters.

The limited number of trials and the different parameters used for both adjunct treatments, NMES and monopolar dielectric diathermy, limit our ability to provide direct recommendations for clinical practice. Further RCTs with larger sample sizes and comparing different biophysical agent parameters are necessary to inform clinical practice.

Taping does not provide additional benefit to exercise therapy

As a standalone intervention, knee taping has short-term effectiveness in reducing self-reported pain during descending stairs,[82 83] walking[84] and single-leg squatting[85 86] when compared with not using knee taping. However, knee taping in isolation is not considered the best care for PFP[9 78] as it does not address key impairments of this population (eg, hip and quadriceps muscle weakness).[87] Our findings suggest knee taping does not provide additional benefits to people with PFP when combined with exercise therapy. This is irrespective of knee taping technique (eg, patellar medialisation,

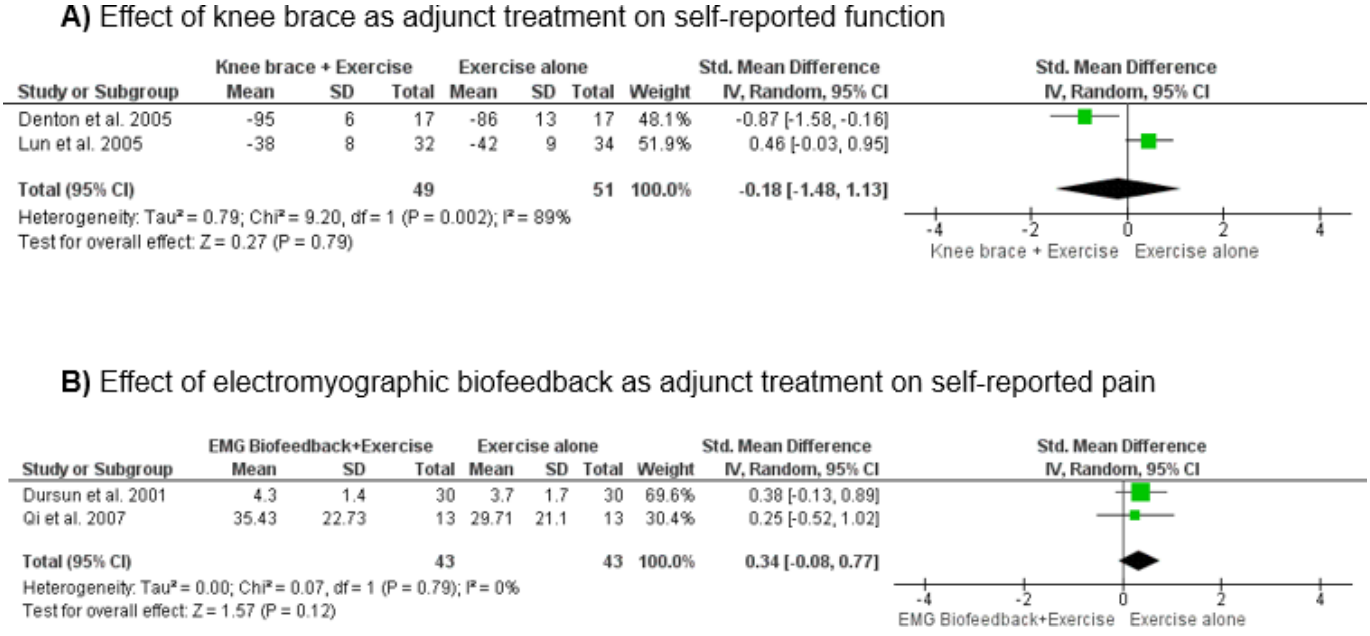


Figure 5 Effects of knee brace combined with exercise therapy (A) and electromyographic (EMG) biofeedback combined with exercise therapy (B) compared with exercise therapy alone for self-reported function and pain, respectively, at short-term (IV, inverse variance). The self-reported function values were inverted to negative to ensure consistent reporting. Denton *et al*[66] assessed the self-reported measure of function using the Anterior Knee Pain Scale, while Lun *et al*[67] assessed it using the Knee Function Scale. Dursun *et al*[74] assessed the self-reported measure of pain using the Visual Analogue Scale, while Qi *et al*[73] assessed it using the Pain Severity Scale.

patellar taping, kinesio taping), as evidenced by our sensitivity analyses (online supplemental file 9).

Previous systematic reviews[11 15] have advocated for taping in the management of PFP. Barton *et al*[11] found moderate evidence for patellar taping and recommended its use in exercise rehabilitation to improve functional capacity. Additionally, Logan *et al*[15] concluded that taping can complement traditional exercise therapy. However, these reviews did not evaluate the effectiveness of taping combined with exercise therapy, and based their conclusion on only a few trials. Findings from new trials[32 33 48–52] and the inclusion of appropriate comparators generated by our review should be used to update clinical practice guidelines and international consensus statement recommendations.[9 78]

Other adjunct interventions

Whole-body vibration: in contrast to our findings, evidence suggests that combining whole-body vibration with exercise therapy has improved self-reported pain and knee function in people with knee osteoarthritis[88–90] compared with exercise therapy alone. There are only a limited number of trials exploring whole-body vibration in people with PFP, with the first trial published in 2018.[61] The considerable methodological heterogeneity among the pooled trials may also be a confounder to our findings (eg, vibratory platform frequency, intervention duration, small sample size). Therefore, further trials with larger samples and low risk of bias may change our findings.

Knee brace: our result is supported by previous systematic reviews,[14 17 91] which did not find additional benefits to self-reported pain and function of patellar bracing compared with exercise therapy alone. Additionally, the pooled analysis, with considerable statistical heterogeneity (I^2=89%), included only two trials exhibiting a high risk of bias. Despite our results not supporting wearing a knee brace to improve self-reported pain and function, wearing a knee brace seems to reduce fear of movement in people with PFP, which could facilitate exercise therapy in fearful patients.[92 93]

EMG biofeedback: the pooled analysis included only two trials with high risk of bias, and its results align with other systematic review,[94] where the quality of evidence does not conclusively support its effectiveness for people with PFP. The efficacy of EMG biofeedback has been assessed in various populations, including those who underwent knee surgery, with conflicting findings.[95 96] Consistent with our findings, a recent systematic review[97] found no significant difference in self-reported pain or function when comparing the combination of EMG biofeedback with exercise with exercise alone in individuals with knee osteoarthritis in the short-term. The use of EMG biofeedback has not been recommended by clinical practice guidelines for PFP management.[9 78]

Quality of the interventions' description

Except for five trials,[43 46 60 72 76] which had moderate-quality descriptions for both interventions, and one trial,[71] which had moderate-quality and good-quality descriptions for adjunct treatment and exercise therapy, respectively, the overall quality of intervention descriptions was generally poor. Poor intervention description limits the ability of clinicians to translate the findings of RCTs into clinical practice. This highlights the need for future trials to improve the description of whether the intervention was modified, how it was delivered and how adherence was assessed.

Strength and limitations

The strengths of our review include the use of a prespecified protocol with no language and date restriction criteria, the inclusion of only RCTs and the summary of the certainty of the evidence using the GRADE approach. Our review was designed to be comprehensive with a robust search strategy. As limitations, no trials were rated as low risk of bias. Each pooled analysis was based on a limited number of trials, and the interventions exhibited inherent differences (eg, multiple taping techniques were applied across the studies) that might make it difficult to draw definitive conclusions about the effectiveness of specific adjunct treatments. There is a lack of comparator to control for placebo effects, particularly for biophysical agents and knee taping, such as sham interventions.[98] Additionally, all pooled analyses were conducted solely in the short-term. Some trials included populations with a wide age variation, and this should be considered when interpreting our findings.

Implication for clinicians

Our findings suggest that NMES and monopolar dielectric diathermy, combined with exercise therapy, may improve self-reported pain. However, knee taping, when used with exercise therapy, does not appear to improve self-reported pain or function. These results are based on short-term effects and are supported by evidence of very low certainty. Additionally, NMES trials exhibited a wide variety of parameters, making it challenging to draw definitive conclusions. Although trials using monopolar dielectric diathermy had slight variations in parameters, the fact that the two trials were from the same author group presents challenges in extrapolating their results to the PFP population. Despite a wide variety of knee taping techniques across the trials, the lack of knee taping effects remained consistent across different techniques, as evidenced by our sensitivity analyses. These recommendations are based on very low-certainty evidence, highlighting the need for high-quality research on this topic with interventions that are better described to facilitate knowledge translation.

CONCLUSION

There is very low-certainty evidence that NMES and monopolar dielectric diathermy combined with exercise improve self-reported pain in people with PFP compared with exercise alone. Very low-certainty evidence suggests that knee taping, whole-body vibration, EMG biofeedback and knee brace do not offer additional benefits to exercise alone in improving self-reported pain and function. Most interventions are poorly described, which is detrimental to translating research knowledge into clinical practice.

Correction notice This article has been corrected since it published Online First. The correct figure 4 has now been replaced.

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