Journal of Bodywork & Movement Therapies 24 (2020) 222–232

Contents lists available at ScienceDirect

Journal of Bodywork & Movement Therapies

journal homepage: www.elsevier.com/jbmt

Prevention and Rehabilitation

Calf stretching and plantar fascia-specific stretching for plantar fasciitis: A systematic review and meta-analysis

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ARTICLE INFO

Article history:
Received 1 July 2019
Received in revised form
8 June 2020
Accepted 13 June 2020

Keywords:
Plantar fasciitis
Plantar fascia-specific stretching
Calf stretching
Tendon
Achilles stretching

ABSTRACT

Background: Plantar fasciitis (PF) is the most common cause of heel pain. A calf stretching (CS) and a plantar fascia-specific stretching (PFSS) are two stretching techniques commonly administered by health care providers.
Objective: To evaluate the literature on the application of these two stretching techniques in the treatment of PF and investigate their effectiveness and efficacy.
Method: A search of PubMed, Web of Sciences, PEDro, CINHAL and Scopus was conducted. Studies that applied stretching as a co-intervention were excluded. The risk of bias was assessed to determine the internal validity of the included trials. The GRADE approach was adopted to determine the overall quality. Pooled analysis was performed to determine the treatment effects of CS and PFSS in terms of the mean difference in the visual analog scale pain score.
Results: Eight articles were found that represented randomized controlled trial and met the inclusion criteria. There was very low-quality evidence that the combined CS and PFSS was less effective in the short term than the other therapies. Comparison between CS and PFSS revealed moderate quality evidence for a larger effect of pain score reduction for PFSS treatment over CS, while very low-quality evidence supported that combined CS and PFSS or CS alone was superior to sham stretching.
Conclusion: There was moderate to very low-quality evidence of the effectiveness of stretching for PF. The treatment effect of stretching was large and comparable to other therapies. Future trials of higher quality are needed to clarify findings or to confirm findings.

1. Introduction

Plantar fasciitis (PF) is one of the most common disorders of the foot (Schleip, 2012; Schneider et al., 2018), and approximately 11–15% of adults with such foot symptoms require professional care (Yang et al., 2017). Within the general population, the incidence of PF typically peaks between 40 and 60 years of age (Schneider et al., 2018). However, the pathogenesis of plantar fascia is currently not well understood (Schleip, 2012). Nonetheless, one of the most common causes includes tightness of the calf muscles and/or Achilles tendons (Oakes, 2005).

Clinical symptoms of inflammatory plantar fascia tend to increase gradually. The plantar heel pain occurs in the first step in the morning after the foot has been non-weight bearing for an extended period (Neufeld and Cerrato, 2008; Uden et al., 2011). The pain is intensified after prolonged weight bearing and gradually increases with activity and often increases towards the end of the day (Cole et al., 2005; Neufeld and Cerrato, 2008; Yang et al., 2017). This pain decreases and stiffness increases overnight, with the pain gradually disappearing until waking up and taking the first weight-bearing step down out of bed (League, 2008; Pećina and Bojanić, 2004). The diagnosis of PF is mainly based on the patient's history and clinical examination (Cole et al., 2005; Yang et al., 2017). Physical examination shows a localized tenderness on the plantar fascia at the origin of the plantar medial tubercle of calcaneal tuberosity (Schleip, 2012). Evaluation of the range of movement (ROM) may reveal a restricted ROM of the ankle dorsiflexion, indicating that there is contracture of the gastrocnemius or Achilles tendon (Neufeld and Cerrato, 2008; Radford et al., 2006).

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https://doi.org/10.1016/j.jbmt.2020.06.013
1360-8592/

Muscle weakness and neurovascular examination should be assessed in order to exclude other possibilities to obtain the correct diagnoses (Neufeld and Cerrato, 2008). While radiography is not necessary in the diagnosis of PF, it can rule out similar symptoms from a calcaneal stress fracture (Schneider et al., 2018), whereas advanced imaging, such as magnetic resonance imaging and ultrasonography, is not necessary for the diagnosis of non-traumatic PF (Schneider et al., 2018).

A conventional multiple-treatment approach is commonly administered by health care providers, consisting of controlling the inflammation, managing pain and promoting healing (Garrett and Neibert, 2013). Stretching is one of the conservative treatments for PF (Garrett and Neibert, 2013; Neufeld and Cerrato, 2008; Pećina and Bojanić, 2004; Schneider et al., 2018). Many modalities, such as shockwave therapy (SWT), steroid injection, taping, foot orthosis, therapeutic ultrasound and electrical stimulation, have been proposed to reduce the inflammation for pain relief (Gutteck et al., 2019). Furthermore, some treatments may have side effects, e.g., plantar fascia rupture in individual receiving steroid injections (Landorf and Menz, 2008; Tatli and Kapasi, 2009), and some require specialist treatment, e.g., ultrasound-guided corticosteroid injection (Schulhofer, 2013). In contrast, the stretching method is generally safe (Landorf and Menz, 2008) and can provide benefits, such as prevention, enhancing the sport performance and improving the ROM and activities (Engkananuwat et al., 2018; Kamonseki et al., 2016).

Two stretching techniques were specified in this review, Achilles tendon or calf stretching (CS) and plantar fascia-specific stretching (PFSS). Both the calf muscle and plantar fascia connect with each other as part of the superficial back line (Myers, 2009) and work across the ankle during walking or running activities. Many randomized control trials (RCTs) have claimed a beneficial effect and ability of conventional therapy when used in conjunction with a combined CS and PFSS program in reducing the pain in patients with PF (Celik et al., 2016; Kumnerddee and Pattapong, 2012; Pfeffer et al., 1999; Renan-Ordine et al., 2011). Some research has revealed that the conjunction of CS alone (Donley et al., 2007; Osborne and Allison, 2006) or PFSS alone (Elizondo-Rodriguez et al., 2013; Rompe et al., 2015; Stratton et al., 2009) could provide a more considerable outcome measure of the plantar heel pain as well. So far, the pooled treatment effects of the two different techniques has not been investigated. Therefore, the objective of this review was to evaluate and synthesize the available evidence regarding the effects of CS and PFSS for PF treatment via a systematic literature review and meta-analysis.

2. Method

The review protocol was registered on the International Register of Systematic Reviews (PROSPERO) on 21/06/2018 code CRD42018098763. The systematic review was organized and reported based on the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement (Moher et al., 2010).

2.1. Search strategy and exclusion data

Database searching was conducted in PubMed/Medline for RCTs which investigated the effectiveness of stretching for PF by using the Medical Subject Headings (MeSH): stretching[All Fields] AND ("fasciitis, plantar" [MeSH Terms] OR ("fasciitis" [All Fields] AND "plantar" [All Fields]) OR "plantar fasciitis" [All Fields] OR ("plantar" [All Fields] AND "fasciitis" [All Fields])) AND ("randomized controlled trial" [Publication Type] OR "randomized controlled trials as topic" [MeSH Terms] OR "randomized controlled trial" [All Fields] OR "randomised controlled trial" [All Fields]).

Four other four electronic databases: Web of Sciences, PEDro, CINHAL and Scopus, were also searched using the search terms 'plantar fasciitis' and 'plantar heel pain' to search for articles on stretching. The search was performed for articles up to April 2017.

Five eligibility criteria were used, as follows:

(1) Type of studies: RCT with parallel or crossover.
(2) Type of control intervention: No treatment, other active interventions or usual care, sham.
(3) Type of intervention: CS or PFSS alone, together or used as additional intervention with other therapeutic intervention.
(4) Type of participant: Adults (>18 y old) with a PF diagnosis or plantar heel pain;
(5) Type of outcome: Pain visual analog scale (VAS) or numerical rating score (NRS), on a 0–10 subscale assessed short-term (immediately after treatment or < 3 months) or long-term (≥3 months) follow-ups.

2.2. Data collection

Data were collected using a form based on the checklist of the Cochrane Handbook for systematic reviews of interventions (CHSRI) (Higgins and Green, 2011). Data extraction was performed by using a pre-defined data abstraction sheet. Independent researcher extracted the following data: Author (year), study design, participants' sample size, demographics and male/female ratio, interventions in terms of intervention groups, exercise prescription (sets/repetitions) and outcome measures, and finally the main finding.

2.3. Risk of bias assessment

Two experienced reviewers independently assessed the risk of bias according to the recommendation of Cochrane Collaboration's tool (Higgins and Green, 2011). In particular, the following domains were assessed: (1) detection bias: blinding of outcome assessment; (2) attrition bias: incomplete outcome data; and (3) reporting bias: selective reporting. The criterion of performance bias was not used because it was not possible to blind therapists and participants for the stretching exercises. The reviewers assigned a judgment of low, high or unclear risk of bias. Disagreements were addressed by obtaining a consensus between two reviewers. Summing up selection, detection and attrition bias, the overall risk of bias in individual studies was considered low if at least three domains met the low-risk criteria; high if two or more domains met the high-risk criteria; and unclear otherwise. The risk of bias across studies was assessed with reporting bias.

2.4. Qualitative analysis

Studies were grouped according to treatment intervention: CS or PFSS or both. For each outcome and each assessment time point, the following comparisons were investigated: PFSS and CS, stretching and no treatment, stretching and another type of intervention, additional stretching to other intervention(s) and other intervention(s). The key outcome considered in the review was pain intensity, assessed with a VAS for pain considered the mean difference and standard deviation as a statistical index.

A meta-analysis of eligible studies was conducted. Data were entered into Review Manager (RefMan 5, The Cochran Collaboration, Oxford, UK). Statistical heterogeneity was assessed using the chi-squared test and I^2 statistic, where a value of $P < 0.1$ indicated significant heterogeneity. According to the I^2 results, heterogeneity was considered as not important (0–40%), moderate (30–60%), substantial (50–90%) or considerable (75–100%) (Higgins and Green, 2011). A fixed-effect model was used when the heterogeneity was considered as not applicable. Otherwise, the randomized-effects model was adopted. Mean differences in continuous outcomes were used to express the intervention effect in each study, and the summary effect estimate was calculated as a weighted average. The weighted mean differences (WMD), which were reported with a 95% confidence interval (CI), were adopted to analyse the total effect comparisons, and $p < 0.05$ was accepted as statistically significant.

2.5. GRADE approach

To assess the overall quality of the evidence for each outcome, the GRADE approach (Guyatt et al., 2008), as recommended in the CHSRI (Higgins and Green, 2011) and adapted in the updated Cochrane Back Review Group (CBRG) method guidelines (Furlan et al., 2009), was applied. Domains that decreased the quality of evidence in this review include: (1) Limitation of study design (>25% of participants from studies with a high risk of bias), (2) Inconsistency (opposite direction of effects or/and significant statistical heterogeneity), (3) Indirectness (only one gender or specific age group included), (4) Imprecision (too few participants or only one study included) and (5) Publication bias across all trials (asymmetry in funnel plot or early publication of positive results). A four-point rating scale, which ranged from 'High quality' to 'Very low quality' was used. To qualify as high-quality evidence, more than 75% of the RCTs within a comparison had to be judged according to: (1) have no limitations of the study design, (2) have consistent findings among multiple studies, present (3) direct (generalizable) and (4) precise data (5) without known or suspected publication bias. The quality of the summary of findings was rated as moderate, low or very low if one, two or three of the criteria were not met, respectively.

The definitions of the evidence quality were adopted from GRADE (Guyatt et al., 2008), which allocated the level of quality into five levels of:

(1) High quality: further research is likely to have an important impact on our confidence in the estimate of effect;
(2) Moderate quality: further research is likely to have an important impact and may change the estimate;
(3) Low quality: further research is very likely to have an important impact on our confidence in the quality in the estimate of effect and is likely to change the estimate;
(4) Very low quality: very uncertain about the estimate;
(5) No evidence: no RCTs are identified that addressed this outcome.

3. Results

3.1. Study selection

In total, 176 articles were identified from five databases. After removal of the duplication, 92 articles were left. Then, after screening for relevant in abstract, 24 articles were excluded. A total of 68 related articles were included in the full text reviewing, but 59 of these were excluded from the analysis for the following reasons: 19 articles were excluded for not being a randomized trial, 1 study included participants without PF, 4 did not have a 0–100 VAS pain scale data, 9 had not applied stretching as an intervention and 26 applied stretching as a co-intervention. Thus, nine articles representing RCTs investigated the effectiveness of CS or/and PFSS met our inclusion criteria. However, one RCT (Porter and Shadbolt, 2005) was excluded as although it compared combined stretching with other therapies, it lacked standard deviation values, which are necessary for a meta-analysis. Therefore, eight RCTs were finally selected for this meta-analysis. Fig. 1 shows the screening and study selection procedure, while the study characteristics, such as the details of study interventions, outcome measures used, follow-up period, results, and dropouts are shown in the Table 1.

3.2. Risk of bias assessment

Our study adopted five of the eight risks of bias criteria. Blinding of subject and therapist were not possible for stretching exercises. Also, we did not identify other apparent sources of bias in the trial. Two reviewers assessed the risk of bias criteria for the eight included articles (see Figs. 2 and 3). Agreement between the review authors was over 50%. Based on the Cochrane risk of bias criteria judgment, four trials (40%) were at a low risk of bias (Kamonseki et al., 2016; Radford et al., 2007; Rompe et al., 2015, 2010). Randomly generated sequences were judged as a low-risk criterion in six trials (Alotaibi et al., 2015; Hyland et al., 2006; Kamonseki et al., 2016; Radford et al., 2007; Rompe et al., 2015, 2010). Five trials described an adequate allocation concealment (DiGiovanni et al., 2003; Kamonseki et al., 2016; Radford et al., 2007; Rompe et al., 2015, 2010). Blinding of outcome assessors were judged as low risk of bias in one trial only (Kamonseki et al., 2016). Five trials were judged as reporting an unclear risk of selective reporting bias (Alotaibi et al., 2015; Digiovanni et al., 2006; DiGiovanni et al., 2003; Hyland et al., 2006; Radford et al., 2007).

3.3. Outcomes

3.3.1. Combined stretching

There was very low-quality evidence that combined CS and PFSS was less effective for the short-term treatment of plantar heel pain (MD = 3.66 (95%CI: 6.77, 14.09); P = 0.49, $I^2 = 53\%$) than the other therapies (see Fig. 4). For subgroups, the exercise was less effective (MD = −1.56 (95%CI: 10.27, 7.15); P = 0.73, $I^2 = 0\%$), while taping provided a greater improvement (MD = 19 (95%CI: 7.51, 30.49); P = 0.001, heterogeneity not applicable for a single trial) (see Fig. 4). Compared with sham and no treatment, there was very low-quality evidence that the combined CS and PFSS had a greater efficacy than sham (MD = −14 (95%CI: 21.07, −6.93); P < 0.0001, heterogeneity, not applicable for a single trial) and no treatment (MD = −16 (95% CI: 23.57, −8.43; P < 0.0001, heterogeneity not applicable for a single trial).

3.3.2. CS and PFSS

Moderate quality evidence was found for a larger effect of PFSS over CS. Pain score reduction was significantly higher in the PFSS group, both in the short term and the long term. The overall effect presented by the mean difference favored the PFSS group (MD = 12.37 (95%CI: 7.63, 17.10); P < 0.00001, $I^2 = 14\%$) (see Fig. 5). A very low-quality evidence was found for CS over sham. The results indicated that the VAS score reduction was significantly greater in the CS group than in the sham group in the short term (MD = −11.40 (95%CI: 23.37, 0.57); P = 0.06, heterogeneity not applicable for a single trial).

Very low evidence was available for the PFSS regarding heel pain reduction compared to SWT. A single study with multiple outcome measures investigated the effectiveness of PFSS in the short term (3-month) and long term (>3-month) revealed a statistically significant improvement in favor of the PFSS compared with SWT in the short term only (MD = −25.68 (95%CI: 32.30, −19.08); P < 0.00001, $I^2 = 0$) (see Fig. 6). The overall effect of PFSS exhibited a significant effect of improvement (MD = −13.52 (95%CI: 23.82, −3.23) P = 0.01, $I^2 = 83\%$) (see Fig. 6). There was moderate evidence of the benefit of adding PFSS to other therapies compared to other therapies alone (MD = −13.46 (95%CI: 16.00, −10.92; P < 0.00001, $I^2 = 83\%$) (see Fig. 7). The results from the meta-analysis indicated the additional

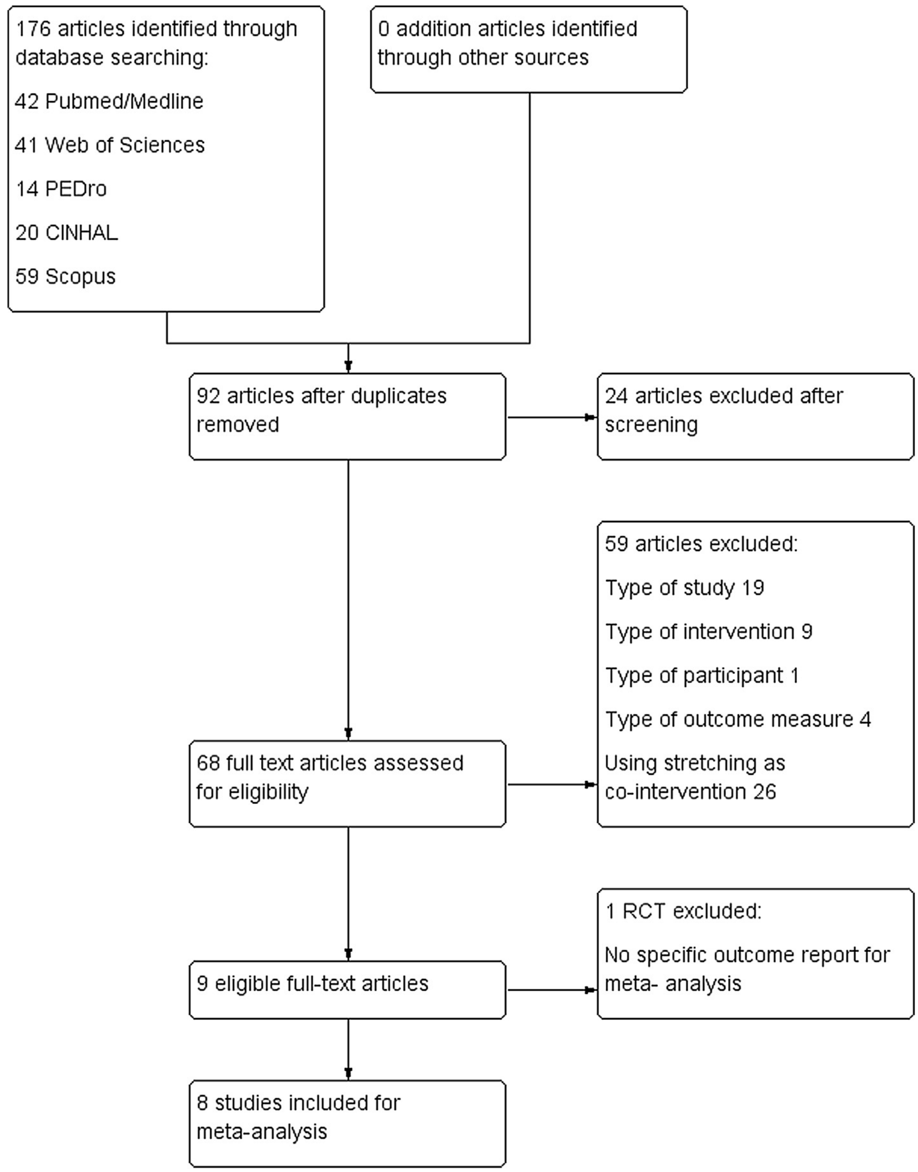


Fig. 1. Flowchart of the results of the literature search.

effect of PFSS was greater than SWT alone in the short term (MD = −22.48 (95%CI: 26.67, −18.30; $P < 0.00001$, $I^2 = 0\%$) and the long term (MD = −10.01 (95%CI: 13.49, −6.53; $P < 0.00001$, $I^2 = 0\%$) (see Fig. 7). A summary of the findings for the effectiveness/efficacy of stretching on PF is shown in Table 2.

4. Discussion

Only eight articles representing RCTs that investigated the effectiveness of CS or/and PFSS met the inclusion criteria of this study. The results indicated that there was moderate quality evidence of a better VAS pain score reduction in the PFSS group than in the CS group. There was very low-quality evidence that combined CS and PFSS was less effective than the other therapies, such as exercise and taping, in the short term. Very low-quality evidence was also available for PFSS, but it was superior to SWT. There was moderate quality evidence that the addition of PFSS to other therapies was superior to other therapies alone, and very low-quality evidence that the efficacy of combined CS plus PFSS or CS alone was better than sham treatment.

Recently, there have been only a few articles published that discuss the effectiveness or efficacy of stretching on PF (Almubarak and Foster, 2012; Sweeting et al., 2011). The results of this meta-analysis supported the previous qualitative review (Sweeting et al., 2011) in terms of the relative effectiveness of CS compared to PFSS. However, some results are contradictory to the previous narrative review when comparing stretching with other therapies (Almubarak and Foster, 2012). Additionally, our results found that adding PFSS to other therapies was superior to other therapies alone in terms of a long-term lasting effect.

It has been suggested that steroid injection, which was the widespread practice for treating PF (Celik et al., 2016; Neufeld and Cerrato, 2008), could be related to adverse effects (Celik et al., 2016; Pećina and Bojanić, 2004; Yang et al., 2017), whereas stretching is not harmful to the nearby tissues, and adverse effects rarely happen. However, the mechanisms of those therapies are not similar. The recovery phase of stretching is slower than steroid injection. Pain may become worse in the first day of stretching since the tightening tissue was stretched, but the pain becomes better once the tightened tissue is reverted back to the normal range. As a

Table 1
Characteristics of the included studies.

Author/study design	Participants	Interventions	Outcomes	Results	Side effects
	Total no./setting/diagnostic criteria/ age/Gender/country	Intervention details (n per group/integrity of intervention/co-intervention)	Outcomes and time points collected	D for continuous data/Significant difference between group (SB), no significant difference between groups (N)	
Kamonseki et al. (2016) Study design: Single-blind RCT	Total no. = 83 Diagnostic criteria: Pain on the plantar face of the heel, or in the middle portion of the central band of the plantar fascia with the following features: 1) Pain upon palpation 2) Insidious pain onset 3) Pain was accentuated after long periods of upright activities or after rest 4) Reduction in pain following light activities	3 groups: 1. Stretching alone (SA) (n = 28) - Stretching hamstrings, ankle plantar flexor, soleus muscle, gastrocnemius muscle, and plantar fascia 2. Foot exercise (FE) (n = 27) - As per SA plus strengthening exercise for extrinsic and intrinsic foot muscles 3. Foot and hip exercise (FHE) (n = 28) - As per SA and FE + abductor and lateral rotator muscles of the hip Total intervention period = 8 weeks	Outcomes: - VAS - FAOS - SEBT Time points collected: Before and after the last treatment session	↓ VAS ↑ FAOS ↑ SEBT/N	N/A
Alotaibi et al. (2015) Study design: RCT	Total no. = 44 Diagnostic criteria: - Tenderness to pressure at the origin of the plantar fascia on the medial tubercle of the calcaneus - Complaint of heel pain greater than or equal to 3 on a 1–10 VAS scale	2 Groups: 1. Monophasic pulsed current (MPC) (n = 22) - Frequency = 100 pulses/s - 3 sessions/week, 4 weeks 2. MPC coupled with PFSS exercises (n = 22) - PFSS exercise 3 times/d, 4 weeks	Outcomes: - VAS - Heel tenderness threshold - Functional activity levels: ADL/FAAM Time points collected: Before and after 4 weeks of treatment.	↓ VAS, improvement of heel tenderness threshold & functional activity levels/N	N/A
Rompe et al. (2015) Study design: a randomized, parallel treatment study with a blinded independent observer	Total no. = 152 Diagnostic criteria: - Plantar medial heel pain that culminates either with their first steps in the morning or after prolonged periods of rest for at least twelve months. - Physical examination revealed tenderness at the site of the plantar fascial insertion on the medial calcaneal tuberosity. - Tenderness extended along the plantar fascia, and it increased with exercises that stretch the plantar fascia, including passive toe dorsiflexion.	2 groups: Group 1: Radial SWT (n = 73) − 2000 pulses/session (air pressure of 4 bars) - frequency of 8 pulses/s, three sessions at weekly intervals Group 2: Radial SWT and PFSS program (n = 79) - PFSS three times/d, 8 weeks	Outcomes: - PS-FFI - SROM questionnaire Time points collected: At 2, 4 and 24 months after baseline.	- At 2 months, foot function index (FFI) sum score showed significantly higher changes for the patients managed with SWT plus PFSS than SWT alone, as well as individually for item 2./SB - Significant differences persisted at 4 but not at 24 months. - SWT plus PFSS is more effective than SWT alone.	- Transient reddening of the skin after SWT − 101 of 152 patients reported treatment-related pain of >5 (NRS 0−10)
Rompe et al. (2010) Study design: a randomized, parallel treatment study with a blinded independent observer	Total no. = 102 Diagnostic criteria: - NRS score ≥6 points for pain during the first few steps of walking in the morning - Localized pain on palpation of the proximal plantar fascia	2 groups: Group 1: PFSS program (n = 54) − 3 times/d, 8 weeks Group 2: radial SWT (n = 48) − 2000 pulses/session with an air pressure of 4 bars - Frequency of 8 pulses/s, given weekly, 3 weeks	Outcomes: - PS-FFI - SROM questionnaire Time points collected: 0, 2, 4 and 15 months after baseline.	- At 2 months, PS-FFI showed significantly greater changes for the patients managed with PFSS than with SWT as well as individually for item 2. - These findings persisted at 4 months. - At 15 months, no significant between-group difference.	- Transient reddening occurred after SWT - 41 of 48 patients in Group 2 reported treatment-related pain of ‡5 (NRS 0−10)
			Outcomes:		

Table 1 (*continued*)

Author/study design	Participants	Interventions	Outcomes	Results	Side effects
	Total no./setting/diagnostic criteria/ age/Gender/country	Intervention details (n per group/integrity of intervention/co-intervention)	Outcomes and time points collected	D for continuous data/Significant difference between group (SB), no significant difference between groups (N)	
Radford et al. (2007) Study design: A randomized, participant-blinded trial	Total no. = 92 Diagnostic criteria: Diagnosed with plantar heel pain defined as: (i) Localized pain at the plantar heel (ii) Worst when first standing or walking after rest (iii) Improved initially after first standing but worsened with increasing activity	2 groups: Group 1: CS and sham ultrasound (n = 46) - Use a wooden stretching wedge - At least 5 min/d, 2 weeks - 3 min of sham ultrasound Group 2: control group (n = 46) - Sham ultrasound	- VAS - Foot health status questionnaire domains of foot pain, foot function, footwear and general foot health - Ankle range of motion moreover, foot posture Time points collected: 0 and 14 d	- Both treatment groups improved over the two weeks of follow-up/ N	– 10 participants in the stretching group experienced an adverse event. However, most events were mild to moderate and short-lived.
Hyland et al. (2006) Study design: a prospective, experimental, randomized, single-factor, pretest/posttest design	Total no. = 41 Diagnostic criteria: - Pain with first steps upon waking (greater than or equal to 3 on a 0-to-10 VAS scale), - Pain located at the heel or plantar surface of midfoot consistent with PF (defined as pain immediately upon awakening and pain with walking or jogging), - Presence of an everted calcaneus ≥ 2°	4 groups: 1. Stretching of the plantar fascia (n = 10) - Passive stretching of the ankle plantar flexors and plantar fascia on days 1 and 3 or 4 2. Calcaneal taping (n = 11) - Keep tape 24 h/d 3. Control (no treatment) (n = 10) 4. Sham taping (n = 10) - keep tape 24 h/d	Outcomes: - VAS - PSFS Time points collected: Pretreatment and 1 week after treatment (post-treatment).	- Calcaneal taping was shown to be a more effective tool for the relief of plantar heel pain than stretching, sham taping, or no treatment./SB - No significant difference among groups for PSFS.	N/A
Digiovanni et al., 2006 Study design: prospective RCT	Total no. = 66 Diagnostic criteria: - Exhibited maximal tenderness with palpation at the origin of the plantar fascia on the medial calcaneal tubercle, confirming a diagnosis of proximal plantar fasciitis.	2 groups: Group A: Plantar fascia tissue-stretching protocol (n = 39) - 3 times/d Group B: Achilles tendon stretching protocol (n = 27) - 3 times/d All patients received prefabricated full-length soft insoles.	Outcomes: - Pain subscale of the FFI - Questionnaire related to pain, function and satisfaction with treatment Time points collected: 8 week and 2 year follow-up.	- ↓ pain of both groups: 8-week (SB), 2-year (N) - The 2-year follow-up results showed marked improvement after implementation of the PFSS exercises, with an exceptionally high rate of improvement for those in the original group treated with the Achilles tendon-stretching program.	N/A
DiGiovanni et al. (2003) Study design:	Total no. = 101 Diagnostic criteria: - Complained of maximum pain upon palpation of the origin of the plantar fascia on the medial calcaneal tubercle, consistent with a diagnosis of proximal plantar fasciitis	2 groups: 1. Group A: Plantar fascia tissue-stretching program (n = 46) - Stretching 3 times/d 2. Group B: Achilles tendon-stretching program (n = 36) - Stretching 3 times/d All patients received prefabricated soft insoles.	Outcomes: - Pain subscale of the FFI - SROM Time points collected: After eight weeks.	- Pain subscale scores of the FFI showed significantly better results for those in the PFSS program for items 1 (worst pain) and 2 (first steps in the morning).	N/A

Abbreviation: ADL = Activities of Daily Living; CS = Calf stretching; d = day; F = Female; FAAM = Foot and Ankle Ability Measure; FAOS = Foot and ankle outcome score; FFI = Foot Function Index; M = Male; NRS = Numeric rating scale; PF = Plantar fasciitis; PFSS = Plantar fascia-specific stretching exercise; PS-FFI = Pain subscale of the validated Foot Function Index; PSFS = Patient-specific functional scale; SD = standard deviation; SEBT = Star Excursion Balance Test; SROM = patient-relevant outcome measures; SWT = Shock-wave therapy; VAS = Visual analogue scale; y = year.

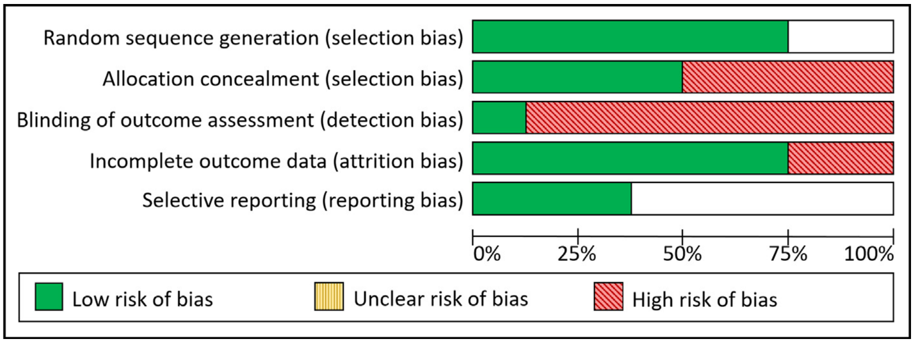


Fig. 2. Risk of bias summary.

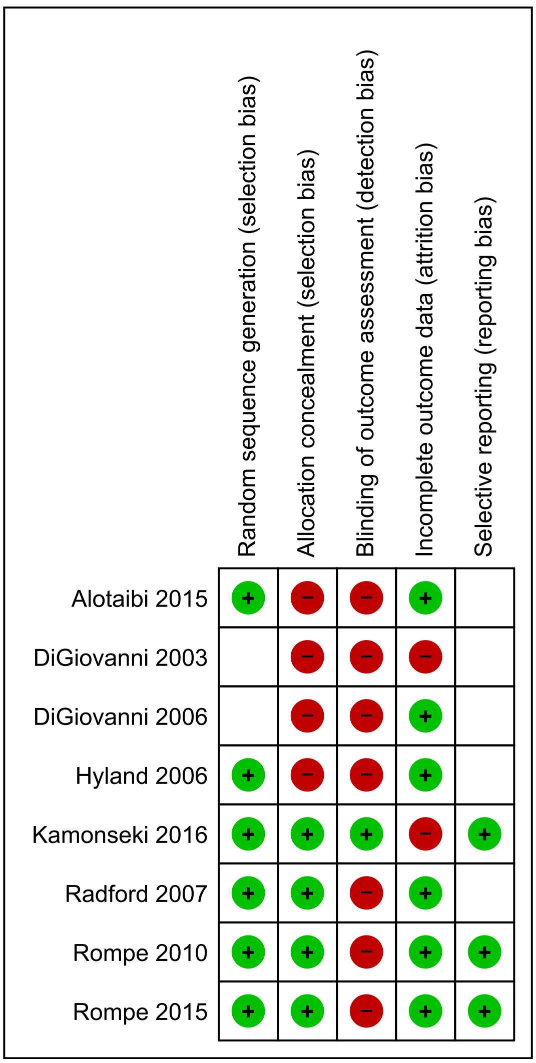


Fig. 3. Risk of bias summary for each included trial.

result, the fascia could be capable of tolerating a normal/abnormal level of stress from loading and activities.

Our review provided and supported evidence of the positive effect of PFSS. Previous publications about the PFSS reported a short-term benefit when compared to the extracorporeal SWT using the best evidence synthesis (Woitzik et al., 2015). This study additionally provided the forest plot of the treatment mean of PFSS when compared to SWT ($P < 0.00001$) for overall short-/long-term effects, which indicated that the treatment effect of PFSS could be comparable to other therapies as a key intervention in the management of PF, especially for short-term goals.

We downgraded five of the seven comparisons to very low-quality evidence (combined stretching vs. other therapies, combined stretching *vs.* sham, combined stretching *vs.* no treatment, CS *vs.* sham, and PFSS *vs.* SWT). Of those, four comparisons (combined stretching vs. sham, combined stretching *vs.* no treatment, CS *vs.* sham, and PFSS *vs.* SWT) included only a single trial for analysis that downgraded those comparisons to very low quality. Two moderate pieces of evidence (CS vs. PFSS and PFSS & SWT *vs.* SWT) were obtained from two RCTs, which had no serious limitation/inconsistency, no serious indirectness, no serious imprecision and no publication bias. A future study focusing on combined CS and PFSS, CS alone or PFSS alone, should improve the quality of evidence and may provide a new insight with a more robust conclusion.

As compared between CS and PFSS, our review found a benefit of a PFSS over CS (15.43 points on the 0–100 scale) in the short term. This finding could be explained by two reasons. Firstly, the specific anatomical structure under stretch may have influenced their effectiveness, where CS is focused on either the Achilles tendon or the calf muscle, while the actual damage is located at the plantar fascia. Therefore, the specific stretching at the plantar fascia seems better as it can cure at the real lesion. Secondly, the weight-bearing position of CS might cause pain during stretching and so the full stretching is impossible. Based on our results, the physical support of non-weight bearing by PFSS could promote a better benefit of stretching in reducing pain.

There was considerable variation in the duration and frequency of the stretching technique applied. In this review, we found a wide variation in the duration of stretching applied, ranging from 10 s to 60 min for CS and from 10 to 30 s for PFSS, while the duration of treatment ranged from 4 d to 8 weeks. Five studies applied participants' self-stretching, while only one study using therapist-applied stretches. Additionally, three studies allowed the co-intervention during the stretching program. Thus, the available evidence does not allow us to set up firm conclusions regarding the optimal frequency of stretching for PF. These results reflect the variability in clinical practice in terms of stretching that is generally based on the degree of impairment and of the clinician's perspective.

4.1. Clinical implications

Based on our finding, PFSS is recommended for treatment of PF for short-term goals. The effectiveness for pain may not be suitable for some people who are seeking a quick and larger treatment effect regardless of adverse effects. Our findings also highlighted that PFSS provided a larger treatment effect for pain reduction compared to CS. The other point highlighted is that the size of the treatment effect of CS and PFSS could be the isolated treatment as it is comparable to other conservative treatments, such as exercise,

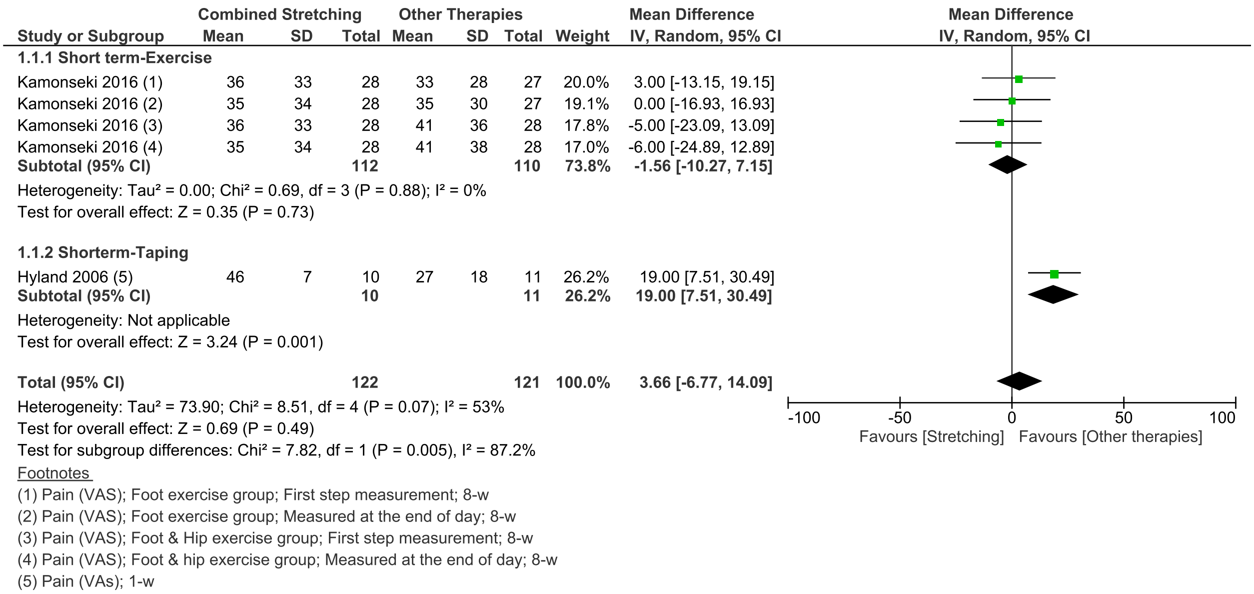


Fig. 4. Forest plot of the comparison between combined CS and PFSS with other therapies.

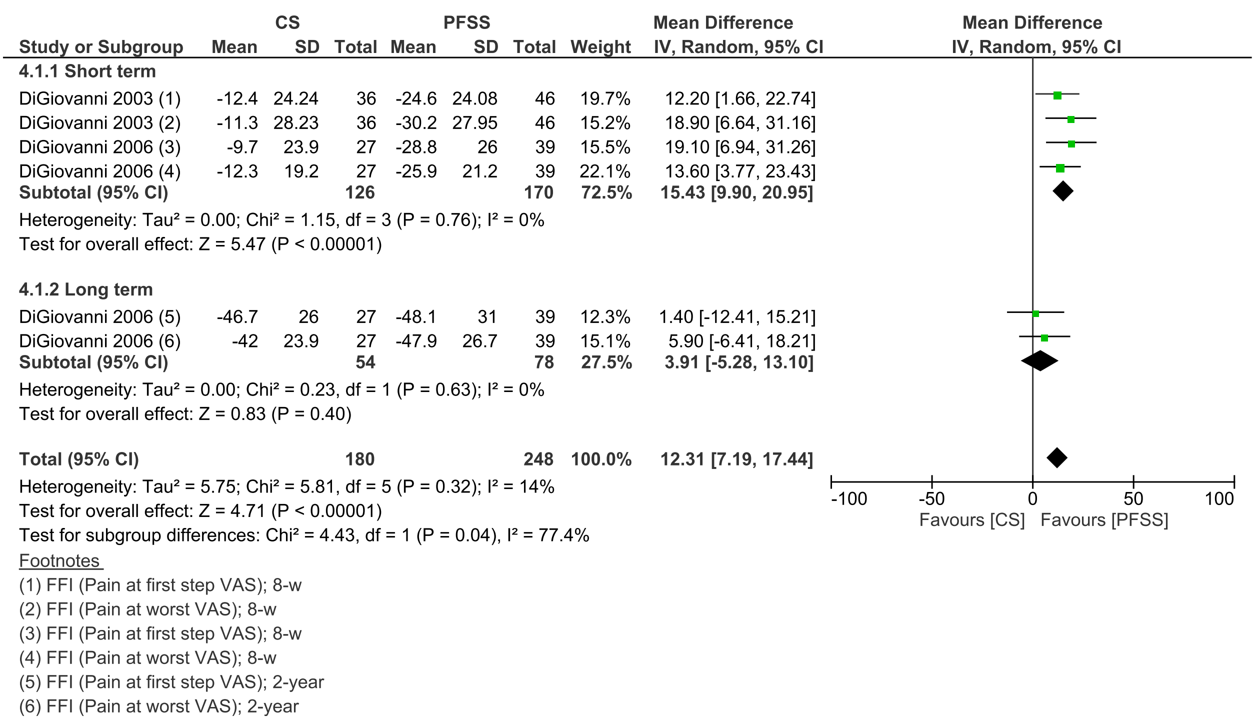


Fig. 5. Forest plot of the comparison between CS and PFFS.

taping and SWT. This benefits both researcher and practitioner who look for simple, effective and conservative intervention methods such as stretching.

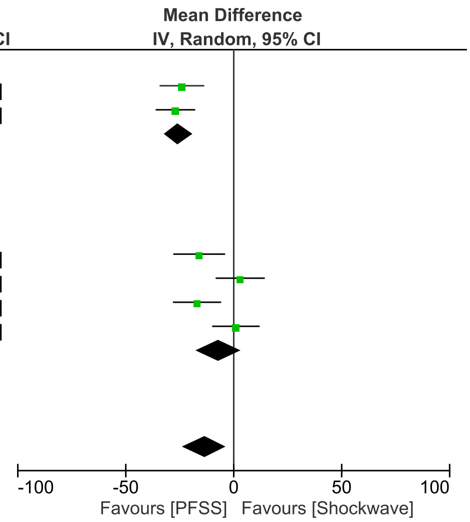
4.2. Strengths

This review is the first meta-analysis to determine the effectiveness of the CS and/or PFSS techniques for the treatment of PF. The strengths of this systematic review are that it was conducted in accordance with the methods recommended by the CBRG. Also, this review focused on the clinically meaningful outcome measures of pain and performed a comprehensive literature search strategy to avoid publication bias using PubMed and three other databases recommended for sensitive searching in the health sciences (http://guides,library.utoronto.ca). The methodological quality of included studies was assessed using the risk of bias scale, a rigorously developed and evaluated scale that is both valid and reliable. Moreover, the strength of recommendations was reported in accordance with GRADE guidelines. Finally, these meta-analysis findings demonstrated the mean treatment differences of pain that would be clinically meaningful for practitioners.

4.3. Limitations

Firstly, there were a limited number of trials included in the analysis, which downgraded the evidence to a very low quality. Future

Study or Subgroup	PFSS Mean	PFSS SD	PFSS Total	Shockwave Mean	Shockwave SD	Shockwave Total	Weight	Mean Difference IV, Random, 95% CI
6.1.1 Short term								
Rompe 2010 (1)	-44	27	50	-20	23	46	16.9%	-24.00 [-34.01, -13.99]
Rompe 2010 (2)	-45	24	50	-18	20	46	17.6%	-27.00 [-35.81, -18.19]
Subtotal (95% CI)			**100**			**92**	**34.5%**	**-25.69 [-32.30, -19.08]**
Heterogeneity: Tau² = 0.00; Chi² = 0.19, df = 1 (P = 0.66); I² = 0%								
Test for overall effect: Z = 7.61 (P < 0.00001)								
6.1.2 Long term								
Rompe 2010 (3)	-55	26	48	-39	31	45	16.0%	-16.00 [-27.67, -4.33]
Rompe 2010 (4)	-61	26	42	-64	25	40	16.4%	3.00 [-8.04, 14.04]
Rompe 2010 (5)	-52	25	48	-35	28	45	16.5%	-17.00 [-27.81, -6.19]
Rompe 2010 (6)	-58	23	42	-59	26	40	16.6%	1.00 [-9.64, 11.64]
Subtotal (95% CI)			**180**			**170**	**65.5%**	**-7.17 [-17.68, 3.34]**
Heterogeneity: Tau² = 83.32; Chi² = 10.89, df = 3 (P = 0.01); I² = 72%								
Test for overall effect: Z = 1.34 (P = 0.18)								
Total (95% CI)			**280**			**262**	**100.0%**	**-13.52 [-23.82, -3.23]**

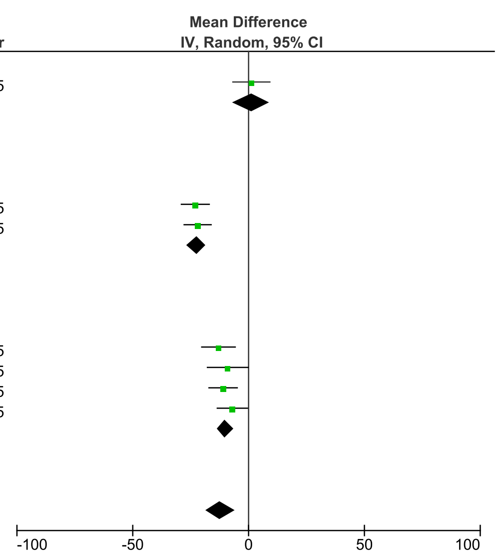


Heterogeneity: Tau² = 136.82; Chi² = 29.25, df = 5 (P < 0.0001); I² = 83%
Test for overall effect: Z = 2.57 (P = 0.01)
Test for subgroup differences: Chi² = 8.54, df = 1 (P = 0.003), I² = 88.3%

Footnotes
(1) FFI (Pain at worst VAS); 8-w
(2) FFI (Pain at first step VAS); 8-w
(3) FFI (Pain at worst VAS); 16-w
(4) FFI (Pain at worst VAS); 15-m
(5) FFI (Pain at first step VAS); 16-w
(6) FFI (Pain at first step VAS); 15-m

Fig. 6. Forest plot of the comparison between PFSS and SWT.

Study or Subgroup	PFSS & Shockwave Mean	PFSS & Shockwave SD	PFSS & Shockwave Total	Shockwave Mean	Shockwave SD	Shockwave Total	Weight	Mean Difference IV, Random, 95% CI	Year
7.1.1 Short term-ES									
Alotaibi 2015 (1)	35.5	2	22	34.3	19	22	13.5%	1.20 [-6.78, 9.18]	2015
Subtotal (95% CI)			**22**			**22**	**13.5%**	**1.20 [-6.78, 9.18]**	
Heterogeneity: Not applicable									
Test for overall effect: Z = 0.29 (P = 0.77)									
7.1.2 Short term-Shockwave									
Rompe 2015 (2)	-47	15	72	-24	21	70	14.9%	-23.00 [-29.02, -16.98]	2015
Rompe 2015 (3)	-40	15	72	-18	20	70	15.1%	-22.00 [-27.83, -16.17]	2015
Subtotal (95% CI)			**144**			**140**	**30.0%**	**-22.48 [-26.67, -18.30]**	
Heterogeneity: Tau² = 0.00; Chi² = 0.05, df = 1 (P = 0.81); I² = 0%									
Test for overall effect: Z = 10.53 (P < 0.00001)									
7.1.3 Long term-Shockwave									
Rompe 2015 (4)	-50	21	69	-37	22	67	14.1%	-13.00 [-20.23, -5.77]	2015
Rompe 2015 (5)	-51	25	65	-42	25	60	12.9%	-9.00 [-17.77, -0.23]	2015
Rompe 2015 (6)	-51	16	69	-40	20	67	14.9%	-11.00 [-17.10, -4.90]	2015
Rompe 2015 (7)	-64	21	65	-57	16	60	14.6%	-7.00 [-13.52, -0.48]	2015
Subtotal (95% CI)			**268**			**254**	**56.5%**	**-10.01 [-13.49, -6.53]**	
Heterogeneity: Tau² = 0.00; Chi² = 1.63, df = 3 (P = 0.65); I² = 0%									
Test for overall effect: Z = 5.64 (P < 0.00001)									
Total (95% CI)			**434**			**416**	**100.0%**	**-12.24 [-18.54, -5.93]**	



Heterogeneity: Tau² = 59.89; Chi² = 36.27, df = 6 (P < 0.00001); I² = 83%
Test for overall effect: Z = 3.80 (P = 0.0001)
Test for subgroup differences: Chi² = 34.59, df = 2 (P < 0.00001), I² = 94.2%

Footnotes
(1) Pain (VAS); 4-w; ES = Electrical Stimulation
(2) FFI (Pain at worst 0-10 scale); 8-w
(3) FFI (Pain at first step 0-10 scale); 8-w
(4) FFI (Pain at first step); 16-w
(5) FFI (Pain at first step); 24-m
(6) FFI (Pain at worst); 16-w
(7) FFI (Pain at worst); 24-m

Fig. 7. Forest plot of the comparison between PFSS&SWT and SWT.

trials on the current topic are therefore recommended. Secondly, the outcome measurements, other than VAS, were not used in all included trials. Without that information, we could not discern the overall outcome of various dimensions in patients with PF. Thirdly, because of the clinical heterogeneity found, the effects of stretching programs covered in the present study may be contained with the confounding effect from a clinical setting. The practitioner or researcher who adopted the stretching protocol should interpret the results with caution. Lastly, the majority of included trials lack long-term data, and we could provide only short-term (up to 3 months) comparative data in all of the comparisons. Further studies, which take these variable into account, is therefore needed.

Table 2
Summary of the effectiveness/efficacy of stretching on PF.

Comparison(Experiment *vs.* control)	No of study/Participants (Experiment/Control)	Quality criteria					GRADE	Mean difference (96%CI); p-value
		Limitations	Inconsistency	Indirectness	Imprecision	Publication bias		
Combined stretching *vs.* other therapies	2 (122/121)	Serious limitations	Serious inconsistency	No serious indirectness	No serious imprecision	Asymmetrical funnel plot	Very low	3.66 (−6.77, 14.09) P = 0.49
Combined stretching *vs.* Sham	1 (10/10)	Serious limitations	–	No serious indirectness	Serious imprecision	Suspicious lag bias	Very low	−14.00 (−21.07, −6.93) P = 0.0001
Combined stretching *vs.* No treatment	1 (10/10)	Serious limitations	–	No serious indirectness	Serious imprecision	Suspicious lag bias	Very low	−16.00 (−23.57, −8.43) P < 0.0001
CS *vs.* PFSS	2 (180/248)	Serious limitations	No serious inconsistency	No serious indirectness	No serious imprecision	Undetected	Moderate	12.37 (7.63, 17.10) P < 0.00001
CS *vs.* Sham	1 (92/92)	No serious limitations	–	No serious indirectness	Serious imprecision	Suspicious lag bias	Very low	−11.40 (−23.37, 0.57) P = 0.06
PFSS *vs.* SWT	1 (280/262)	No serious limitations	–	No serious indirectness	Serious imprecision	Asymmetrical funnel plot	Very low	−13.52 (−23.82, −3.23) P = 0.01
PFSS & SWT *vs.* SWT	2 (434/416)	No serious limitations	Serious inconsistency	No serious indirectness	No serious imprecision	Undetected	Moderate	−13.46 (−16.00, −10.92) P < 0.00001

5. Conclusion

Moderate quality evidence is available for the positive effect of PFSS over CS and the use of PFSS with SWT was better than SWT alone. There is very low-quality evidence that combined stretching was superior to other therapies and PFSS alone was better than SWT. The treatment effect of stretching is not small and comparable to other therapies. Future trials of higher quality may improve some of the findings of this review.

CRediT authorship contribution statement

Akkradate Siriphorn: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing - original draft, Writing - review & editing. **Sukanya Eksakulkla:** Conceptualization, Formal analysis, Investigation, Methodology, Validation, Writing - original draft.

Declaration of competing interest

None.

Acknowledgements

The authors would like to express our sincere thanks Associate Professor Dr. Nithima Purepong for her valuable guidance, suggestions, and encouragement from the initial to the final of this study.

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