The effect of exercise therapy versus foot orthoses on individuals with patellofemoral pain syndrome: a literature review

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PREFACE

The following literature review is a graduation assignment for the bachelor of applied sciences at Hanze University of Applied Sciences in Groningen, The Netherlands. The subject concerns two common interventions used in treating a type of knee pain with a high prevalence amongst an active population. Both, foot orthoses and exercise therapy are used to treat patients who have the patellofemoral pain syndrome (PFPS). The topic became of interest to me when reading a book which criticised the usage of foot orthoses. At Hanze University of Applied Sciences I have learned that patients' recovery success is higher when internal means are utilized, especially in non-specific conditions. During a webinar on running injuries Leonardo DaVinci's statement, "simplicity is the ultimate sophistication" came to my attention. I do not consider foot orthoses as the most suitable option for treating PFPS with internal means and in a simplistic way. Clients are being made dependent on devices too frequently. After reading the controversies on the usefulness of exercise therapy or foot orthoses I decided that investigating this topic further could benefit the professionals who work with clients suffering from PFPS, in particular physiotherapists in their every-day practice.

ABSTRACT

Background

Exercise therapy interventions and foot orthoses are two treatment options for the common patellofemoral pain syndrome (PFPS). The evidence on the effect of foot orthoses is conflicting and the evidence for exercise therapy to be effective is high. Therefore the two interventions have been compared in several studies.

Aim

This review aims to combine literature's findings to answer the research question: What is the effect of exercise therapy versus foot orthoses on (i) pain levels and (ii) patient perceived global improvement in adults with patellofemoral pain syndrome?

Methods

The databases PubMed, PEDro and CINAHL were searched for available literature. Eligible were RCTs, published after 2000 that compared exercise therapy to foot orthoses in patients with PFPS using pain and patient perceive global improvement as an outcome measure. Included studies were evaluated for quality using the PEDro scale, data was compared and best evidence synthesis executed.

Results

Four RCTs were included. Their quality ranged from 4 to 8 out of 10 points on the PEDro score. Three out of four studies showed no significant and clinically relevant effects on pain and patient perceived improvement scores. One pilot RCT found significant differences in worst pain VAS scores in favour of the exercise therapy group. Within-group effect sizes were medium to large on all outcome measures.

Conclusion

This review shows that there is conflicting evidence for statistically significant and clinically relevant between-group differences when comparing exercise therapy to foot orthoses regarding (i) pain and (ii) perceived global improvement in patients having PFPS. Three out of four RCTs do not find clinically relevant results. Only one pilot RCT found statistically significant between-group differences. Both treatments seem to have clinically meaningful effects on patients with PFPS on pain levels and patient perceived global improvement.

Keywords: patellofemoral pain syndrome, anterior knee pain, foot orthoses, exercise therapy, physiotherapy

INTRODUCTION

The patellofemoral pain syndrome (PFPS) is a common musculoskeletal complaint with a reported incidence rate of 22 in 1000 per year with women being 2.33 times more likely affected (Boling, Padua, Marshall, Guskiewicz, Pyne et al., 2010). PFPS is categorized as anterior knee pain (AKP) and is often considered a non-specific complaint (Houghton, 2007). Amongst runners, PFPS was reported to be the most common diagnosis in a retrospective case analysis from 2002 (Taunton, Ryan, Clement, McKenzie, Lloyd-Smith et al., 2002).

Despite its non-specific nature, there are various biomechanical theories about the pathophysiology of PFPS. The condition is often believed to be caused by patella maltracking (Draper, et al., 2009). Maltracking of the patella could be induced by multiple factors. One factor is a pronated foot type with increased rear-foot eversion causing tibial internal rotation. Tibial internal rotation may lead to a dynamic valgus of the knee. Valgus of the knee could lead to patella maltracking (Petersen, et al., 2014). Pronation is a natural movement of the foot and a term that is widely used, but not well understood. A clinical definition for over-, hyper- or excessive pronation has not been established yet. Therefore, the usage of these terms is advised against (Nigg, Behling, & Hammil, 2019). In this review, these terms will be used in the context of prevalent studies which refer to them.

Pronation of the foot leading to patella maltracking is not the only possible reason for experienced complaints. The cause of PFPS is multifactorial. Strength of the hip abductors could have an impact as well as vastus medialis/vastus lateralis disbalance, hamstring tightness or iliotibial tract tightness (Petersen, et al., 2014). Furthermore, tibial and femoral rotations have influence on patellofemoral biomechanics, joint contact area and pressures with different underlying mechanisms. Additionally, it might not be altered biomechanics in the patellofemoral joint which is causing complaints but more chronic overloading in combination with athletic activity (Lee, Morris, & Csintalan, 2003). Evidence shows that PFPS patients often have dominant psychological factors which might hinder recovery. (Jensen, Hystad, Kvale, & Baerheim, 2007). Symptoms of PFPS include peripatellar pain upon exercising or activities of daily living (ADL) mostly in knee extension (van der Heijden, Lankhorst, van Linschoten, Bierma-Zeinstra, & van Middelkoop, 2015).

A common intervention for PFPS are foot orthoses. Foot orthoses cover the plantar surface of the foot and benefit the foot only upon weight bearing. The goal of foot orthoses is mostly to provide support to various foot types. (Webster & Murphy, 2019). Guidelines from the Journal of Orthopaedic & Sports Physical Therapy 2019 and a consensus statement from 2018 recommend prescribing foot orthoses for patients presenting with greater than normal pronation to reduce PFPS related pain for the short term (Collins, et al., 2018) (Willy, et al., 2019). However, the empirical evidence about the effectiveness of foot orthoses is low or conflicting (Petersen, et al., 2014) (Webster & Murphy, 2019). On one hand, studies have found no relation between AKP and excessive foot pronation (Hetsroni, et al., 2006). Although it is widely believed that overpronating runners are at higher risk for running-related injury such as PFPS, this belief has not has been supported by reliable studies (Hintermann & Nigg, 1998). On the other hand, evidence found foot orthoses to be effective (Braga, et al., 2019) and associations between pronation and running injuries are recognizable with weak evidence. (Nigg, Behling, & Hammil, 2019)

Foot orthoses should be combined with exercise therapy (Willy, et al., 2019) (Collins, et al., 2018). Exercise therapy mostly consists of lower extremity coordination and strengthening exercises (Cardoso, Caputo, Rombaldi, & Del Vecchio, 2017). The evidence for exercise therapy in PFPS is high and supporting closed kinetic chain, strengthening exercises for lower limb musculature, in combination with flexibility training. Daily exercising of two to four sets of ten or more repetitions over a period of six weeks or more is recommended (Harvie, O'Leary, & Kumar, 2011).

Considering the above-mentioned controversies, it is important to gain a deeper insight into current evidence on the use of foot orthoses to manage PFPS. Investigating the conclusions of studies directly comparing foot orthoses with exercise therapy could help practitioners in decision making. Furthermore, this review will summarize the current knowledge on exercise therapy versus foot orthoses in PFPS treatment. While Barton et al. have published a review about the efficacy of foot orthoses in treating individuals with PFPS in 2010, this literature search will identify RCTs comparing foot orthoses and exercise therapy. In 2010 Barton's review only found one randomised clinical trial (RCT) comparing the two aforementioned interventions with sufficient quality (Barton, Munteanu, Menz, & Crossley, 2010). Therefore, the research question of this review is the following: What is the effect of exercise therapy versus foot orthoses on (i) pain levels and (ii) patient perceived global improvement in adults with patellofemoral pain syndrome?

METHODS

Study design

A preliminary literature search indicated that there is empirical data available on the research question. Therefore, to answer the research question, a literature review was chosen since it can summarize the existing data and update the current evidence. The search was performed by one researcher in February and March 2021.

Search procedure

The databases PubMed, the Physiotherapy Evidence Database (PEDro) and the Cumulative Index to Nursing and Allied Health Literature (CINAHL) were searched for suitable articles. PubMed is widely used in health sciences (Ossom Williamson & Minter, 2019). PEDro is a database specific for the field of physiotherapy. Published RCTs are rated with the PEDro scale. CINAHL is a smaller database than PubMed. It emphasises specifically on nursing and its allied professions. Appendix 1 shows how the final search strings were chosen.

On PubMed's and CINAHL's advanced search option Boolean operators were used to create the following search string: ("Anterior knee pain" OR "Patellofemoral Pain Syndrome" OR "Runner's knee") AND ("Insoles" OR "Foot orthoses" OR "Orthotics") AND ("Exercise therapy" OR "Physiotherapy" OR "gait training" OR "Physical therapy" OR "Exercising").

Boolean operators cannot be used in the search procedure on PEDro. The advanced search option was chosen using the terms: Knee pain foot orthoses.

On all databases a filter was applied to exclude studies published before 2000. On PubMed and CINAHL a filter was applied to only display RCTs. On PubMed Mesh terms were included by searching each search term in "all fields".

Study selection procedure

One researcher screened the titles and abstracts found on the mentioned databases for eligibility using the inclusion and exclusion criteria listed in Table 1. Full text RCTs published after 2000 comparing foot orthoses and any form of exercise therapy to improve pain and patient perceived global outcome in adults with PFPS were included. PFPS should be diagnosed by the patient experiencing pain around the patella upon activities. Exclusion criteria were knee injuries and pathologies, history of knee surgery and referred pain from the hip or spine.

Table 1: Eligibility criteria for literature of this review

Study characteristics	Inclusion	Exclusion
Publication date	Published after 2000	Published before 2000
Access	Full text	full text not available
Language	English, German, Dutch	Other than English, German, Dutch
Study design	RCT	Research designs other than RCTs
Population	Adults with PFPS (Antero-medial knee pain when performing functional tasks like squatting, running or prolonged sitting)	Children, pathology or injury of the knee, previous knee surgery, referred pain from LB or hip
Interventions	Comparing orthoses and exercise therapy	Other than foot orthoses and physiotherapy, only one intervention
Outcome	Pain (VAS or NPRS), global improvement scores	Other than VAS or NPRS and global improvement scores

RCT= Randomized controlled trial, PFPS= Patellofemoral pain syndrome, LB= Low back, NPRS= Numeric pain rating scale, VAS= Visual analogue scale

Methodological quality assessment

For the evaluation of the RCTs the PEDro scale was used (Maher, Sherrington, Herbert, Moseley, & Elkins, 2003). It entails 11 items and the total score ranges from 0 to 10. The methodological quality of the RCTs was classified based on cut-off points namely: Poor (≤3), fair (4-5), good (6-8), excellent (9-10) (Cashin & Auley, 2020). The PEDro score has an interrater reliability with intraclass correlation coefficients of 0.53 to 0.91 for physiotherapeutic interventions. The individual items have Kappa scores of 0.36 to 1.00 for physiotherapeutic trials (Cashin & Auley, 2020).

Data extraction

Main characteristics extracted from the identified studies to interpret the included findings were the following: Author and year of publication, study design, population characteristics such as sample size, age, gender and duration of PFPS symptoms, interventions, comparisons, as well as outcome measures and main results. Primary outcome measures were decided to be the Visual Analogue Scale (VAS) or Numeric Pain Rating Scale (NPRS) for pain, as well as the global outcome scores which indicate a global improvement or worsening of an individual’s well-being. Secondary outcomes were any pain and functioning related measurements which were deemed to be relevant to answer the research question. The main results to be extracted were between-group differences of the intervention and comparison group. If the findings between-group were mostly non-significant, within-group differences and minimal clinically important difference (MCID) were analysed to determine the effectiveness of the interventions individually.

Data analysis

Statistical analysis determined the significance (p-value or confidence interval (CI)) of the findings. A p-value below 0.05 or CI of 95% was defined to be statistically significant. An improvement (MCID) of > 20mm/ >2 points on the VAS/ NPRS, respectively was considered to be clinically relevant (Collins, et al., 2009). Additionally, effect sizes were calculated to determine the clinical relevance for primary and secondary outcome measures. Cohen’s d formula was used to calculate the between-/ within-group effect sizes, where possible, to compare the efficacy of both treatment options. In 1988 Cohen, suggested that d values of 0.2, 0.5, and 0.8 represented small, medium and large effect sizes, respectively (Fritz, Morris, & Richler, 2012).

The best evidence synthesis of results of this literature review was determined by a rating system derived from van Tulder et al. (van Tulder, Furlan, Bombardier, & Bouter, 2003). The rating system has been used in previous systematic reviews on PFPS (Barton, et al., 2010) (Heintjes, Berger, & Bierma-Zeinstra, 2003). Table 2 describes the levels of evidence that can be determined.

Table 2: Best evidence synthesis

Level of evidence	Description of evidence
Strong evidence	provided by generally consistent findings in multiple high quality RCTs
Moderate evidence	provided by generally consistent findings in one high quality RCT and one or more low quality RCTs
Limited evidence	provided by only one RCT (either high or low quality)
Conflicting evidence	inconsistent findings in multiple RCTs and CCTs
No evidence	no RCTs

RCT= randomised controlled trial

RESULTS

Search strategy

The search on the databases PEDro, PubMed and CINAHL resulted in 56 studies. After removing duplicates, 31 records were screened by title and abstract. Most were excluded because they did not meet the inclusion criteria. Six full text articles were assessed of which four were eligible for data synthesis. Figure 1 displays the search results according to The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Health Care Interventions: Explanation and Elaboration (Liberati, et al., 2009). PEDro was the only database providing all articles which were analysed in this review.

Methodological quality of included studies

The four included RCTs had PEDro scores ranging from 4 to 8 out of 10 points. Three RCTs have a good quality ((Bonacci, Hall, Saunders, & Vicenzino, 2017) (Collins, et al., 2009) (Matthews, et al., 2020)) and one (Wiener-Ogilvie & Jones, 2004) has a fair quality (Cashin & Auley, 2020). The PEDro total and sub-scores can be viewed in appendix 2.

Characteristics of the studies

The four RCTs included for data extraction were published between 2004 and 2020. The oldest study was published in 2004 (Wiener-Ogilvie & Jones, 2004). Collins et al. published in 2009 (Collins, et al., 2009) and Bonacci et al. in 2017 (Bonacci, Hall, Saunders, & Vicenzino, 2017). The most recent RCT was published by Matthews et al. in 2020 (Matthews, et al., 2020). Two of the four included studies are pilot RCTs ((Bonacci, Hall, Saunders, & Vicenzino, 2017) (Wiener-Ogilvie & Jones, 2004)). Table 4 summarizes the characteristics of the included studies.

Population Characteristics

The total number of participants included in this review was 343, of which 229 are female and 114 male. Bonacci et al. (2017) and Wiener-Ogilvie et al. (2004) were pilot RCTs and therefore have small population sizes (16 and 18 respectively). Collins et al. (2009) and Matthews et al. (2020) have larger sample sizes of 90 and 218 participants, respectively. All studies included an exercise therapy group as well as a foot orthoses group; other experimental subgroups were not included. The mean age of participants was 33.8 years. The mean/median duration of symptoms amongst the participants ranged from 10.6 to 52.3 months.

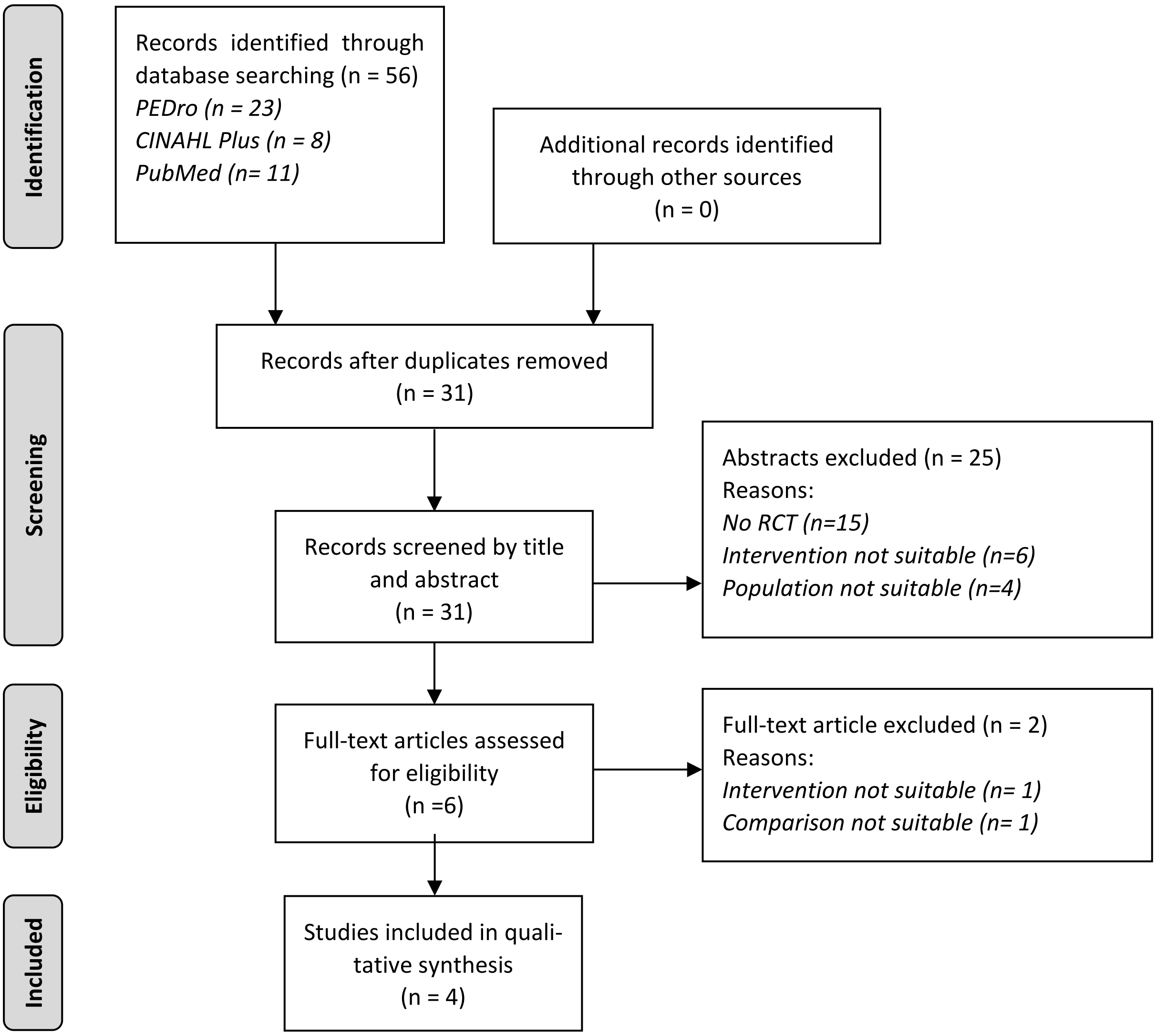

Figure 1 PRISMA flowchart

Intervention characteristics

All physiotherapeutic interventions from the four included RCTs are different in nature.

The exercise therapy intervention in Bonacci et al. (2017) consisted of a gait retraining program. Participants completed 10 supervised gait retraining sessions on a treadmill over six weeks. In the first 4 weeks participants visited a physiotherapist twice per week. Gait retraining included running in a minimalist shoe (Vibram Seeya, Vibram, MA, USA) and a 10% increase in running cadence. The participants were not given instructions on foot strike during running. The gait retraining sessions each week covered 20% of each participant's total weekly training volume. The rest of the training volume was finished without supervision and in the participant's normal running shoe. Within week 1-5 running cadence was supervised by a metronome. During the supervised training sessions, a walk/run program was implemented progressing from 50/50%, to 10/90% walk/run within 5 weeks. In the last week, the full 20% of total weekly training volume consisted of running. The participants ran at their normal training pace (Bonacci, Hall, Saunders, & Vicenzino, 2017).

Collins et al. (2009) chose a multimodal therapy program which included patellar mobilisation, patellar taping, progressive vasti muscle retraining exercises with electromyographic biofeedback, hamstring and anterior hip stretches, hip external rotator retraining, and a home exercises. The participants went to the therapist once per week for six weeks (Collins, et al., 2009).

Matthews et al. (2020) administered a progressive, resisted hip exercises program. Exercises were focused on the hip abductor, external rotator, and hip extensor muscle groups in side- lying, supine and standing, which were performed bilaterally. Participants went to a physiotherapist-supervised exercise session, three times per week for four weeks. Physiotherapists chose lengths and grade of elasticated band at each session. Participants had to achieve a maximum of 10 repetitions and perceived exertion of 5–7/10 per exercise. (Matthews, et al., 2020).

Wiener-Ogilvie et al. (2004) prescribed a progressive exercise program consisting of isometric and isotonic quadriceps contractions without and with resistance, isotonic hamstring contractions, dynamic stepping exercises, hamstring stretching exercises, isometric hip adductor contractions and dynamic side stepping. The participants were advised to exercise the affected leg. The training was supervised over a period of four weeks, the first two weeks twice and the second two weeks once per week. The last four out of eight weeks the participants exercised at home every day (Wiener-Ogilvie & Jones, 2004).

After the described exercise programmes, no recommendations were given to the participants on the continuation of the training in all RCTs. All studies advised against cointerventions; if any were used, they were reported.

Comparison intervention characteristics

The comparison treatments all consisted of orthoses fitting sessions. Three studies include foot-arching exercises ((Bonacci, Hall, Saunders, & Vicenzino, 2017), (Collins, et al., 2009), (Matthews, et al., 2020)).

In Bonacci et al. (2017) and Collins et al. (2009) the foot orthoses group attended orthoses fitting sessions to adjust a prefabricated, commercially available full-length orthoses (Vasyli International, Brisbane, Australia). The orthoses were fitted ensuring that their medial longitudinal arch did not affect motion of the first metatarsophalangeal joint. The customized foot orthoses were adapted to optimize comfort. In one study, the participants were taught to use the orthoses all times in athletic footwear for four weeks or longer (Bonacci, Hall, Saunders, & Vicenzino, 2017). The other study chose fitting sessions for six weeks and orthoses were fitted for four different pairs of shoes. Moreover, participants performed arch forming exercises twice per day (Collins, et al., 2009).

Matthews et al. (2020) fitted prefabricated foot orthoses (Vionics International, Australia) and a pair of orthosis-like sandals. A standardised fitting process prioritising comfort reviewing size, length and hardness was administered. Participants performed home exercises twice per day, consisting of calf stretches and anti-pronation foot exercises. Participants attended six fitting sessions over six weeks. The participants received no instructions on whether to continue or stop wearing the orthoses. (Matthews, et al., 2020).

In Wiener-Ogilvie et al. (2004) the foot orthoses treatment group received medium density EVA foot orthoses. Rearfoot posts and forefoot posts were adjusted using 40° additional wedges, suiting individual agreements and podiatry assessment. Patients saw the podiatrist once per week for eight weeks (Wiener-Ogilvie & Jones, 2004).

Outcome measure characteristics

Bonacci et al. (2017) and Collins et al. (2009) used the average and worst pain VAS to measure pain over the previous week. Matthews et al. (2020) used the average and worst NPRS over the last week. Wiener-Ogilvie et al. (2004) does not specify the timeframe of the VAS pain rating. Primary outcome measures are presented in table 4.

Patient perceived global improvement was measured with the 15-point Global improvement scale (GIS) spanning from −7 ('a very great deal worse') through 0 ('no change') to +7 ('a very great deal better') (Bonacci, Hall, Saunders, & Vicenzino, 2017), a 5-point GIS (Collins, et al., 2009), or a 5-point Global outcome score for knee pain (GOSKP) (Wiener-Ogilvie & Jones, 2004) and the 7-point Global rating of change scale (GRoCS) (Matthews, et al., 2020). Matthews et al. (2020) success was defined as "much better" or "better". Success was decided to equate to ≥+4 ('moderately better') on the 15-point scale in Bonacci et al. (2017). In Collins et al. (2009), success equated marked or moderate improvement on the 5-point Likert scale.

Secondary outcome measures were not homogenous over all four RCTs. The anterior knee pain scale (AKPS) was used in three studies (Bonacci, Hall, Saunders, & Vicenzino, 2017), (Collins, et al., 2009) (Matthews, et al., 2020). The functional index questionnaire was used to assess functioning in one study (Collins, et al., 2009). Amongst other outcomes measures, the knee osteoarthritis outcome score (KOOS) was used by Matthews et al. (2020). Ambulation intensity (AI), transfer intensity (TI) and physical function scale were used in one study (Wiener-Ogilvie & Jones, 2004).

Main result characteristics

Between-group differences

The provided data from the RCTs and calculated data for between- group differences can be seen in Table 3. Main results were extracted for measurement moments between 8 and 12 weeks since all included studies conducted evaluations in this time frame. Data from studies that had evaluations at week 6 are not displayed in table 3. They showed very similar results than the evaluations at 12 weeks. In table 4 statistical significance of measurements at week 6 is included.

Outcome measures for pain showed statistical significance (CI does not include null value) and large effect sizes at 12 weeks on the worst pain VAS (d= 1.74) in favour of the exercise therapy intervention in one study. The between-group effect size for worst and average pain VAS was large (Bonacci, Hall, Saunders, & Vicenzino, 2017). All other studies found slightly more improvement in VAS scores in the exercise therapy group which was not statistically significant (P> 0.05/ P>0.01 in Collins et al. 2009). In Collins et al. (2009) the between- group effect sizes were medium on the worst pain VAS (d= 0.29) and small on average pain VAS (d= 0.11). Matthews et al. (2020) showed small effect sizes in worst and average pain VAS (d=0.18, d= 0.15).

The patient perceived global improvement scores presented success rates of 86% and 29% for the gait-retraining group and foot orthoses group, respectively at 12 weeks in Bonacci et al. (2017). Wiener-Ogilvie at al. (2004) reported a marked improvement of 77.7% and 44.4% for the exercise therapy and foot orthoses group at 8 weeks, respectively. The other two studies reported much smaller group differences in global outcome scores (Collins, et al., 2009) (Matthews, et al., 2020).

The secondary outcome measures partly showed significant differences between the exercise therapy and foot orthoses groups. Bonacci et al. (2017) found scores on the AKPS to be statistically significantly different (CI does not include null value) and large effect sizes (d=2.16) in favour of the exercise therapy intervention. Collins et al. (2009) did not find a significant difference on the AKPS and the functional index questionnaire. In Matthews et al. (2020) there appeared to be small p-values favouring hip exercises versus foot orthoses at 12 weeks on three KOOS subscales (pain(p= 0.032), symptoms (p= 0.028) and daily living(p= 0.037)). The effect sizes of the KOOS between group difference were however, medium (d=0.31, d= 0.26, d= 0.30). Wiener- Ogilvie et al. (2004) did not find any significant differences in AI, TI and physical function scale.

Table 3: statistical significance, effect sizes and marked improvement between group differences at 8 to 12 weeks

Study	Outcome measure	Mean (SD)		Statistical significance (p- value or mean difference (CI))	Effect size Cohen's d	% of participants w. marked improvement	
		ET	orth			ET	orth
Bonacci et al. (2017)	Worst pain VAS	8.43 (14.21)	43.71 (24.86)	Mean (95% CI): −38.64 (−70.63 to −6.64)*	1.74		
	Average pain VAS	4.21 (7.97)	24.14 (17.63)	Mean (95% CI): −12.21 (−28.99 to 4.55)	1.46		
	AKPS	94.14 (4.26)	79.86 (8.32)	Mean (95% CI): 17.21 (7.03 to 27.38)*	2.16		
	GIS					86	29
Collins et al. (2009)	Worst pain	26.8 (22.2)	33.3 (22.2)	Mean (99% CI): −6.5 (−19.2 to 6.2)	0.29		
	Average pain VAS	20.1 (17.8)	22.1 (17.8)	Mean (99% CI): −2 (−12.2 to 8.2)	0.11		
	AKPS	84.9 (9.9)	81.8 (9.9)	Mean (99% CI): 0.9 (−4.9 to 6.6)	0.31		
	GIS	53.4 (32.8	46.7 (32.8)	Mean (99% CI): 0.1 (−1.06 to 1.25)	0.20	83	81
Matthews et al. (2020)	Worst pain NPRS	4.1 (2.5)	4.6 (2.9)	P= 0.13	0.18		
	Average pain NPRS	2.6 (1.8)	2.9 (2.2)	P= 0.14	0.15		
	AKPS	79.3 (9.0)	78.6 (13.4)	P= 0.83	0.06		
	GIS			P= 0.67		50	48
	KOOS symptoms	75.8 (14.4)	71.7 (17.2)	P= 0.028*	0.26		
	KOOS pain	80.7 (11.2)	76.4 (15.9)	P= 0.032*	0.31		
	KOOS daily living	88.6 (9.5)	84.9 (14.9)	P= 0.037*	0.30		
Wiener-Ogilvie et al. (2004)	GIS			P= 0.12		77.78	44.4

*AKPS= Anterior knee pain scale (0–100 points, 100= no disability); CI= Confidence interval, ET= Exercise therapy, GIS= Global improvement score (−100-100), NPRS= Numeric pain rating scale, Orth= Foot orthoses, KOOS= Knee osteoarthritis outcome score, SD= Standard deviation, VAS= Visual analogue scale, *= statistical significance: p<0.05/ p<0.01 or CI does not include null value*

Within-group differences

There is no information on statistical significance regarding within- group differences given in the articles. Wiener-Ogilvie et al. (2004) did not provide sufficient data for effect size calculations. Data from the within-group statistical analysis can be found in appendix 3 Table 7 and 8.

Exercise therapy

All studies that provided data on the VAS/ NPRS show a clinically relevant change in worst pain VAS/NPRS after 8 to 12 weeks where effect sizes appeared to be large. The average pain VAS did not prove clinically relevant changes in Bonacci et al. (2004) and Collins et al. (2009). In Bonacci et al. (2017) and Collins et al. (2009) there is a clinically relevant change (>10 points) in the AKPS. The other two studies did not provide sufficient data for a within group comparison or effect size calculation regarding the AKPS. Global improvement scores show improvements of 50%, 77.78%, 83% and 86% in Matthews et al. (2020), Wiener- Ogilvie et al. (2004), Collins et al. (2009) and Bonacci et al. (2017), respectively. The effect sizes for the KOOS sub-scores in Matthews et al. (2020) showed medium to large effect sizes.

Foot orthoses

On the worst pain VAS/ NPRS and AKPS, out of the studies studies that provided sufficient data, Collins et al. (2009) and Matthews et al. (2020) showed a clinically meaningful change. Effect sizes were medium and large. The average pain VAS did not prove a clinically relevant changes in Bonacci et al. (2004)Collins et al. (2009). Global improvement was 29%, 43%, 44.4% and 81% in Bonacci et al. 2017, Matthews et al. (2020), Wiener-Ogilvie et al. (2004) and Collins et al. (2009), respectively. Secondary outcomes such as the KOOS in Matthews et al. (2020) show medium effect sizes.

Best evidence synthesis

When comparing the effect of exercise therapy with foot orthoses on pain and patient perceived global improvement data from one RCTs with a fair quality and two RCTs with a moderate quality, showed that there are no statistically significant or clinically relevant differences between the two treatments. According to van Tulder et al. (2003) this means that this evidence is strong. There is inconsistent evidence from two RCTs showing large between group differences in patient perceived global improvement scores. The evidence for a statistically significant difference between groups for worst pain VAS improvement within 12 weeks is also inconsistent. Therefore, the level of evidence for the two treatment options being statistically significantly different is conflicting according to van Tulder et al. (2003). Moreover, medium to large within-group effect sizes and clinically relevant changes in outcome measures indicate a strong level of evidence as all RCTS support these findings.

Table 4: Characteristics of the included studies

Study details	Population				Intervention		Comparison		Primary outcome Measures		Main results of primary outcome measures
Author (year); Study design	Groups	Total number, gender	Age (SD)	Duration of symptoms in months	Type of ET intervention	Frequency, duration	Type of Orth intervention	Frequency, duration	Pain	Patient perceived global improvement	stat. sign. of between- group difference after 6, 8 or 12 weeks
Bonacci et al. (2017); Pilot RCT	ET	n= 8 m= 4 f= 4	34.0 (9.5)	Mean= 15.63 SD= 6.61	Gait retraining: running on minimalistic shoe, 10% increase in cadence	10 supervised sessions in 6 weeks	fitted, worn in all athletic footwear, arch forming exercises added	2 visits	Average and worst pain on VAS over last week	15-point GIS	At 6 weeks: No stat. sign. differences for any outcomes At 12 weeks: Worst pain VAS: Stat. sign. between-group mean differences in favour of gait retraining average pain VAS: no stat sign. differences GIS: large between group difference in marked improvement favouring ET
	Orth	n=8 m= 0 f= 8	31.5 (9.7)	Mean= 14.88 SD= 8.41							
Collins et al. (2008); RCT	ET	n= 45 m= 16 f= 29	30.9 (5.8)	Median= 37 Range= 12.3-84.8	Multimodal program: Mobilisation, Strengthening and stretching, knee focussed	6 supervised sessions in 6 weeks	fitted comfortably for 4 shoes, arch forming exercises added	6 sessions in 6 weeks	Average and worst pain VAS	5-point GIS,	At 6 and 12 weeks: Worst and average pain VAS: No stat. sign. difference between groups GIS: no sign. between group differences
	Orth	n= 46 m= 21 f= 25	27.9 (5.3)	Median= 42 Range= 12.3-96							
Matthews et al. (2020); RCT	ET	n= 109 m= 39 f= 70	28.3 (6.0)	Mean= 52.3 SD= 61.9	Progressive, resisted hip exercises	12 supervised session in 4 weeks	fitted comfortably, antipronation exercises	6 sessions in 6 weeks	NPRS	7-point GRoCS	At 6 and 12 weeks: Worst and average NPRS: No stat. sign. between group differences GRoCS: No sign. between group differences
	Orth	n=109 m= 28 f= 81	27.9 (6.0)	Mean= 55.4 SD= 60.8							
Wiener- Ogilvie et al. (2004); Pilot RCT	ET	n= 9 m= 1 f= 8	51 (22.5)	Mean= 10.6 SD= 8.2	Strengthening and stretching program, hip and knee focussed	6 supervised sessions in 4 weeks	fitted	8 sessions in 8 weeks	VAS	5-point GOSKP	at 8 weeks: VAS: Between group differences were not stat. sign. GOSKP: Large between group difference
	Orth	n= 9 m= 5 f= 4	38.7 (17.2)	Mean= 17.9 SD= 17.8							

ET= Exercise Therapy, f= female, GIS= Global improvement scale, GOSKP= Global outcome score for knee pain, GRoCS= Global rating of change scale, n= number, NPRS= Numeric pain rating scale, m= male, orth= foot orthoses, RCT= Randomised clinical trial, SD= Standard deviation, stat. sign.= statistically significant, VAS= Visual analogue scale

DISCUSSION

The aim of this literature review is to answer the research question: What is the effect of exercise therapy versus foot orthoses on (i) pain levels and (ii) patient perceived global improvement in adults with the patellofemoral pain syndrome? The results showed conflicting evidence for statistically significant and clinically relevant between- group differences when comparing exercise therapy to foot orthoses regarding (i) pain and (ii) perceived global improvement in patients having PFPS, whereby three out of four RCTs do not find clinically relevant between-group results. Therefore, effect sizes and MCIDs for within-group differences of the two compared treatments were calculate. It can be concluded that both interventions show medium to mostly large effect sizes for pain outcome measurements. The effect sizes for VAS/ NPRS and AKPS in the exercise therapy intervention were on average higher than for the foot orthoses intervention. The exercise therapy groups have more results with MCIDs than the foot orthoses groups across the RCTs. However, there was a lack of data to calculate effect sizes and MCIDs for all studies. Furthermore, there is no information on statistical significance for within- group difference results given. Therefore, the within-group difference results need to be interpreted with caution.

The results of this review are influenced by the population sample sizes of the compared RCTs. Two RCTs with large sample groups find no significantly different effects of the two interventions on pain and patient perceived global improvement of the PFPS symptoms (Collins, et al., 2009) (Matthews, et al., 2020). Two pilot RCTs with small populations find large differences in the global improvement scores. One study with a small sample size also finds a statistically significant difference in worst pain VAS (Bonacci, Hall, Saunders, & Vicenzino, 2017). Data on statistical significance was inconsistent throughout the studies and biased by small sample sizes.

A methodological limitation of this review concerns the effect sizes. Cohen's d was used for all effect size calculations. However, it should usually only be used for large sample sizes. This review's author used Cohen's d for calculations with a small population sample size in Bonacci et al. (2017). Therefore, the results were analysed with caution since they were much larger than effect sizes from other studies. However, effect size calculations proofed to be necessary. It stood out that Matthews et al. (2020) showed some statistically significant differences in KOOS scores. After calculating the effect sizes, the difference however appeared to be medium and the clinical relevance is questionable. This underlines the conclusion that there is no clinically relevant between-group difference when comparing exercise therapy and foot orthoses in patients with PFPS.

The population of the four compared RCTs is mostly homogenous in age and gender and representative of the epidemiological data collected amongst PFPS patients (Boling, et al., 2010). There are twice as many women in the review's sample group than men. However, in Bonacci et al. (2017) the foot orthoses group only consists of women which is not representative. The participants' age mostly falls under the expected age of below 30 years (Smith, et al., 2018). The exercise therapy groups in Collins et al. (2009) and Wiener-Ogilvie et al. (2004) are the only groups with participants being older than 40 years old. This could influence the results since older participants might suffer from osteoarthritis instead of PFPS (Wiener-Ogilvie & Jones, 2004).

In the RCTs, PFPS is mostly diagnosed through excluding other pathologies. It is never mentioned that the condition is often characterized as non-specific. An explanation for the conflicting literature and non-significant results of this review could be the non-specific nature of PFPS. Since the pathophysiology of the condition is not fully understood yet, the working mechanism of different treatments might not be biomechanically explainable. Literature suggests the nature of PFPS often being related to overloading and not to structural malalignments (Patel & Villalobos, 2017). A biomechanical explanation for the results of this review is focused on the goals of both interventions. Exercise therapy is described to aim at less dynamic valgus of the knee by strengthening the hip stabilizing musculature. Foot orthoses are aimed at limiting dynamic valgus of the knee by limiting tibial internal rotation. From the results of the compared RCTs, it is not recognizable which biomechanical approach is favorable. The two above mentioned non-specific and biomechanical approaches seem to be conflicting. However, an update for physical therapy on AKP suggests that there are patients with pain of non-specific nature and patients who are presenting with patellar instabilities (Werner, 2014).

The exercise therapy programs of the four compared RCTs consist of different exercises and focus on different muscle groups. According to an RCT from 2011, hip strengthening and a coordination program may be useful in a conservative treatment plan for PFPS (Meira & Brumitt, 2011). This review however found larger effects sizes in the gait retraining group (Bonacci, Hall, Saunders, & Vicenzino, 2017) and general lower extremity strengthening and stretching program (Collins, et al., 2009) than in the hip strengthening programme (Matthews, et al., 2020). These findings are supported by an RCT comparing different types of exercises which shows that hip strengthening exercises are not more effective than quadriceps exercises or stretching exercises (Saad, Vasconcelos, Mancinelli, Munno, & Liporaci, 2018). Therefore, the type of exercise therapy program might not be as relevant as often believed (Harvie, O'Leary, & Kumar, 2011).

In the long term, the specific treatment option for PFPS seems to become less relevant. Two out of four RCTs in this review have a comparison group which wears foot orthoses and does an exercise program (Collins, et al., 2009) (Wiener-Ogilvie & Jones, 2004). These combined treatment groups do not show different results than the other groups. Collins et al. (2009) did a final assessment after 52 weeks and found no significant differences between groups. A sham orthoses treatment group in Collins et al. (2009) also showed no significantly different effect than other treatment groups after 52 weeks. Only in the short term a significant difference could be identified in worst pain VAS results when comparing sham orthoses to foot orthoses.

It is frequently stated that orthoses should be prescribed if the foot has greater than normal pronation (Willy R. W., et al., 2019). This is questionable for several reasons; Firstly, Nigg et al. (2019) suggests to avoid the term because there is no clear definition for overpronation. Furthermore, there are numerous clinical trials performed and future studies planned to investigate whether a treatment based on subgroups is beneficial. One of those subgroups is often defined as having a malalignment of the lower extremity which includes pronation of the subtalar joint (Witvrouw, et al., 2005). However, a PFPS assessment recommendation does not mention foot pronation for the examination of PFPS (Fredericson & Yoon, 2006). Also, the subgroups are often found, based on findings from an assessment (Selfe, et al., 2016). It cannot be concluded that these subgroups found in a baseline assessment will have different treatment responses. Therefore, Matthews et al. (2020) divided the foot orthoses group and the exercise therapy treatment group into a low- and a high midfoot mobility group. A high midfoot mobility is here assumed to be related to more pronation when running. They found no evidence for the foot orthoses group with a high midfoot mobility benefiting more from foot orthoses than the low midfoot mobility group. There is however evidence that injured runners use more of their available range of motion. Healthy runners seem to keep a higher eversion buffer. Eversion buffers cannot be assessed by simple range of motion testing most studies do (Rodrigues, TenBroek, & Hamill, 2013). Based on the findings of this review and the literature mentioned, it should be further questioned if pronation is causing PFPS, if pronation in relation to PFPS is assessed correctly and if overpronation exists. If pronation was causing PFPS, foot orthoses should in many cases be superior to e.g. hip strengthening exercises.

In non-specific conditions an active coping and treatment approach is recommended. This has been well researched for low back pain (Luna, et al., 2017). An active approach is correlated to the patients' internal locus of control (Nyland, Cottrell, Harreld, & Caborn, 2006). An internal locus of control promotes recovery (Kendell, Saxby, Farrow, & Naisby, 2001). The foot orthoses promote on one hand an active coping style since the patient consciously decides to wear them daily when being active. On the other hand, they give passive support to the foot. Since an exercise program is encouraging the patient to move it fits better into the principle of active treatment. Psychological factors such as kinesiophobia are sometimes being focused on when dividing PFPS patients into subgroups (Selhorst, Rice, Degenhart, Jackowski, & Tatman, 2015). An active treatment might reduce the psychological symptom of kinesiophobia and is therefore likely to benefit this patient group.

Compared to the systematic review by Barton et al. (2010) this review includes two RCT of sufficient quality for best evidence synthesis and high level evidence conclusion instead of only one. Barton et al. (2010) also included Collins et al. (2009). However, Matthews et al. (2020) could not be included since it was published after Barton's review. Therefore, this review provides more recent evidence.

A strength of this review is that it only includes RCTs having at least one exercise therapy and one foot orthoses group each. Moreover, all RCTs used the VAS/ NPRS and global improvement scores as outcome measures, allowing data collected to be well compared. Since only RCTs were included, the PEDro score could be used for quality assessment in all cases.

A methodological limitation of this review is that a p- value of 0.05 or CI of 95% is described as statistically significant in the methods. However, Collins et al. (2009) used a p- value of 0.01 and CI of 99% to determine that the results are not statistically significant. It was not possible to determine whether results would have been statistically significant if a p value of 0.05 or CI of 95% had been used.

The author of this review recommends to conduct future RCTs with four groups (exercise therapy, foot orthoses, sham orthoses, combined exercise and foot orthoses) carried out in a similar study design as Collins et al. (2009). The sham orthoses group can reveal if exercise therapy or orthoses are better than a placebo treatment. The group sizes should, as in Collins et al. (2009), be based on a power analysis. A study with four intervention main groups could be combined with an approach like in Matthews et al. (2020) where treatment subgroups are identified and analysed. Subgroups could be divided based on recent developments which are looking at the patients pronation buffer used when moving (Rodrigues, TenBroek, & Hamill, 2013). Another option for treatment subgroups could focus on the non-specific nature of PFPS. Therefore, psychosocial factors and changes in training volume as well as intensity should be considered. Furthermore, it would be interesting to gain insight into the economic perspective of the two treatments. Since healthcare is expensive it would be valuable to gain insight into the future healthcare need of the PFPS patients, whereby the most sustainable long term treatment is found and therefore chosen for.

CONCLUSION

This review shows that there is conflicting evidence for statistically significant and clinically relevant between-group differences when comparing exercise therapy to foot orthoses regarding (i) pain and (ii) perceived global improvement in patients having PFPS. Three out of four RCTs do not find clinically relevant between-group results after 8 to 12 weeks. Only one pilot RCT found statistically significant between-group differences. Both treatments seem to have clinically meaningful effects on patients with PFPS on pain levels and patient perceived global improvement.

Implications for practice

For physiotherapists working with clients having PFPS symptoms it is recommended to question whether foot orthoses provide added value to the treatment. According to this review, it is not essential for physiotherapists to prescribe orthoses or refer patients to a podologist. However, the orthoses have no inferior value and therefore can be considered if they do not harm the patients' self- efficacy.

It is beneficial to work with an evidence-based treatment approach, whereby this reviews finding, the patient's wishes and own expertise are taken into consideration.

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APPENDIX

Appendix 1

Table 5 search trials on PubMed, CINAHL and PEDro

Search attempt	Database	goal	Search terms	Filters	Number of hits
1	PubMed	Applying all suitable synonyms	("Anterior knee pain" OR "Patellofemoral Pain Syndrome" OR "Runner’s knee") AND ("Insoles" OR "Foot orthoses" OR "Orthotics") AND ("Exercise therapy" OR "Physiotherapy" OR "gait training" OR "Physical therapy" OR "Exercising")	none	51 -> too many
2	PubMed	Narrowing search down using filter	(("Anterior knee pain"[All Fields] OR "Patellofemoral Pain Syndrome"[All Fields] OR "Runners knee"[All Fields]) AND ("Insoles"[All Fields] OR "Foot orthoses"[All Fields] OR "Orthotics"[All Fields]) AND ("Exercise therapy"[All Fields] OR "Physiotherapy"[All Fields] OR "gait training"[All Fields] OR "Physical therapy"[All Fields] OR "Exercising"[All Fields])	RCT, from 2000	11 -> good -> apply to CINAHL
3	CINAHL	Using different database	("Anterior knee pain" OR "Patellofemoral Pain Syndrome" OR "Runner’s knee") AND ("Insoles" OR "Foot orthoses" OR "Orthotics") AND ("Exercise therapy" OR "Physiotherapy" OR "gait training" OR "Physical therapy" OR "Exercising")	RCT From 2000	8 -> good
4	PEDro	Creating new search string for different database search system	Anterior knee pain patellofemoral pain syndrome	From 2000	9 -> good, but one previously found article missing
5	PEDro	Adjusting search string so that one potentially suitable article can be included	Knee pain patellofemoral pain syndrome	From 2000	23 -> good

RCT= Randomized controlled trial, green= chosen search string

Appendix 2

Table 6 PEDro scale ratings of included RCTs

Study	Ran all	Con all	Bas com	Bli sub	Bli the	Bli ass	Adq fol	itt	Bet com	Poi est	Tot /10

Bonacci et al. (2017)	yes	yes	yes	no	no	no	yes	no	yes	yes	6
Collins et al. (2009)	yes	yes	yes	no	no	yes	yes	yes	yes	yes	8
Matthews et al. (2020)	yes	yes	yes	no	no	yes	yes	yes	yes	yes	8
Wiener- Ogilvie et al. (2004)	yes	yes	no	no	no	no	no	no	yes	yes	4

Adq fol= Adequate follow-up; Bas com= Baseline comparability; Bet com= Between-group comparisons; Bli ass= Blind assessors; Bli sub= Blind subjects; Bli The= Blind therapists; Con all= Concealed allocation; itt= Intention-to-treat analysis; Poi est= Point estimates and variability; Ran all= Random allocation; RCT= Randomised controlled trial; Tot= Total

Appendix 3

Within- group differences

P-values were not given in the articles. Mean and SD’s were not given in Wiener- Ogilvie et al. (2004), therefore the effect size could not be calculated. Furthermore, the average pain NPRS and AKPS baseline measures were not given in Matthews et al. (2020).

Exercise therapy

Table 7 within- group differences in the exercise therapy group

Study	Outcome measure	Mean (SD)		Effect size Cohen’s d
		ET base	ET end	
Bonacci et al. (2017)	Worst pain VAS	43.38 (16.62)	8.43 (14.21)*	2.10
	Average pain VAS	18.13 (11.37)	4.21 (7.97)	1.42
	AKPS	81.88 (7.10)	94.14 (4.26)*	2.09
Collins et al. (2009)	Worst pain	61.4 (15.6)	26.8 (22.2)*	1.80
	Average pain VAS	34.1 (17.0)	20.1 (17.8)	0.80
	AKPS	71.7 (11.3)	84.9 (9.9)*	1.24
Matthews et al. (2020)	KOOS symptoms	68.6 (16.1)	75.8 (14.4)	0.47
	KOOS pain	69.0 (12.9)	80.7 (11.2)	0.97
	KOOS daily living	79.6 (13.1)	88.6 (9.5)	0.79
	Worst pain NPRS	6.3 (2.0)	4.1 (2.5)*	0.97
	Average pain VAS		2.6 (1.8)	
	AKPS		79.3 (9.0)	
Wiener-Ogilvie et al. (2004)				

*AKPS= Anterior knee pain scale (0–100 points, 100= no disability); CI= Confidence interval, ET= Exercise therapy, GIS= Global improvement score (−100-100), NPRS= Numeric pain rating scale, Orth= Foot orthoses, KOOS= Knee osteoarthritis outcome score, SD= Standard deviation, VAS= Visual analogue scale, *= clinically relevant change*

Foot orthoses

Table 8 within- group differences in the foot orthoses group

study	Outcome measure	Mean (SD)		Effect size Cohen’s d
		Orth base	Orth end	
Bonacci et al. (2017)	Worst pain VAS	52.13 (14.63)	43.71 (24.86)	0.41
	Average pain VAS	28.38 (15.31)	24.14 (17.63)	0.26
	AKPS	78.13 (6.56)	79.86 (8.32)	0.23

Collins et al. (2009)	Worst pain VAS	59.4 (15.3)	33.3 (22.2)*	1.37
	Average pain VAS	38.6 (16)	22.1 (17.8)	0.97
	AKPS	70.8 (9.0)	81.8 (9.9)*	1.16
Matthews. (2020)	KOOS symptoms	66.5 (14.8)	71.7 (17.2)	0.32
	KOOS pain	69.0 (12.6)	76.4 (15.9)	0.52
	KOOS daily living	78.8 (13.1)	84.9 (14.9)	0.43
	Worst pain NPRS	6.3 (2.0)	4.6 (2.9)*	0.68
	Average pain NPRS			
	AKPS		78.6 (13.4)	
Wiener-Ogilvie et al. (2004)				

*AKPS= Anterior knee pain scale (0–100 points, 100= no disability); CI= Confidence interval, ET= Exercise therapy, GIS= Global improvement score (−100-100), NPRS= Numeric pain rating scale, Orth= Foot orthoses, KOOS= Knee osteoarthritis outcome score, SD= Standard deviation, VAS= Visual analogue scale, *= clinically relevant change*