Sports Med (2014) 44:1703–1716
DOI 10.1007/s40279-014-0231-5

SYSTEMATIC REVIEW

Outcome Predictors for Conservative Patellofemoral Pain Management: A Systematic Review and Meta-Analysis

Simon Lack · Christian Barton · Bill Vicenzino · Dylan Morrissey

Published online: 7 August 2014

Abstract
Background Patellofemoral pain (PFP) is highly prevalent within both sporting and recreationally active populations. Multiple treatment approaches have been advocated for the management of PFP, attempting to address both intrinsic and extrinsic factors thought to contribute to the development and persistence of pain. A number of predictors of treatment success have been proposed, and evaluated, for directing intervention choice.
Objective Our aim was to systematically review the literature that identifies outcome predictors of specific conservative interventions in the management of PFP, including quality of the current evidence, to guide clinical practice and future studies investigating outcome predictors within this population.
Data Sources The AMED, CINAHL, EMBASE, MEDLINE and Web of Science databases were searched from inception to April 2013.
Study Selection Randomized controlled trials (RCTs) and cohort studies.
Study Appraisal and Synthesis Methods Following initial searching, all potential papers were assessed by two independent reviewers for inclusion using a checklist developed from the inclusion criteria. Cited, and citing, references were also searched in Google Scholar, but unpublished work was not sought. Methodological quality was assessed using a previously designed quality assessment scale. Definitions for levels of evidence were guided by recommendations made by van Tulder et al.
Results Fifteen low-quality (LQ) cohort studies were included. No RCTs were found. This systematic review identified the evaluation of 205 conservative management outcome predictor variables. Of this large number of variables that have been assessed, 19 (9 %) were found to significantly predict a successful outcome. Where two or more outcome predictors and success determinants were consistent between studies, data were pooled. Within these studies, the low number of participants per output variable, and absence of controls, is likely to compromise the validity of the predictor's accuracy. Very limited evidence identified higher functional index questionnaire scores (mean 0.82, 95 % confidence interval [CI] 0.18–1.46), greater forefoot valgus (mean 0.67, 95 % CI 0.05–1.28) and greater rearfoot eversion magnitude peak (mean −0.93, 95 % CI −1.84 to −0.01) to significantly predict improved outcomes with orthoses interventions. Shorter symptom duration ($p = 0.019$), lower frequency of pain ($p = 0.012$), younger age, faster vastus medialis oblique

Electronic supplementary material The online version of this article (doi:10.1007/s40279-014-0231-5) contains supplementary material, which is available to authorized users.

S. Lack · C. Barton · D. Morrissey (✉)
Centre for Sports and Exercise Medicine, William Harvey Research Institute, Bart's and the London School of Medicine and Dentistry, Queen Mary University of London, Mile End Hospital, Bancroft Road, London E1 4DG, UK
e-mail: d.morrissey@qmul.ac.uk

C. Barton
Complete Sports Care, Melbourne, VIC, Australia

C. Barton
Pure Sports Medicine, London, UK

C. Barton
Lower Extremity Gait Studies, Health Sciences, La Trobe University, Bundoora, VIC, Australia

B. Vicenzino
Division of Physiotherapy, School of Health and Rehabilitation Sciences, The University of Queensland, Brisbane, QLD, Australia

reflex response time ($p = 0.026$), negative patella apprehension, absence of chondromalacia patella, tibial tubercle deviation of <14.6 mm and greater total quadriceps cross-sectional area on magnetic resonance imaging ($p = 0.01$), and reduced eccentric average quadriceps peak torque ($p = 0.015$) significantly predicted exercise intervention success following multivariate statistical analysis. Limited evidence identified increased Q-angle (mean 0.38, 95 % CI 0.05–0.72) and very limited evidence identified greater usual pain (mean 0.43, 95 % CI 0.01–0.85) to predict taping intervention success.

Conclusions This systematic review provides a comprehensive summary of current derivation level studies identifying indicators of prediction for conservative PFP management. The overall strength of evidence was low. With appropriate caution, clinicians should consider taping for those with greater usual pain, orthoses for older individuals and exercise for younger individuals, and orthoses intervention for patients with greater forefoot valgus and rearfoot eversion magnitude peak. RCTs with evaluation of outcome prediction as a primary aim are clearly warranted to provide clinicians with robust evidence and facilitate evidence-informed, tailored intervention to this heterogeneous patient population.

1 Introduction

Patellofemoral pain (PFP) has a high prevalence within both sporting and recreationally active populations [1, 2]. Among 2,002 patients presenting to a sports medicine clinic with running-related injuries, 842 (42.1 %) reported knee pain, with 331 (46 %) being diagnosed with PFP [2]. PFP is characterised by the gradual onset of diffuse pain in the retropatellar or peripatellar region that is aggravated during tasks that increase patellofemoral joint (PFJ) loading (e.g. running, jumping, squatting) [3].

Development and persistence of PFP is widely considered to be multifactorial [4], with both extrinsic and intrinsic factors thought to contribute. Proposed extrinsic factors include excessive training load, altered training surface and/or inappropriate footwear. Proposed intrinsic factors can be divided into local (around the knee), proximal (thigh, hip, trunk or pelvis), and distal (foot and lower leg) characteristics [5, 6].

Larger quadriceps angle, sulcus sign, patella tilt angle, and lower peak torque knee extension, hip abduction and external rotation strength have proven association with PFP [7]. However, these studies have methodological weaknesses and the cross-sectional design inhibits determination of causality. Prospectively, limited quadriceps and gastrocnemius flexibility, knee extension weakness and increased knee valgus moment at initial contact when landing have been identified as predictors of PFP development [6]. Most of these studies utilized military populations with resultant limited generalizability to most clinical populations. Put together, the findings from these reviews highlight both the multifactorial nature of PFP and the diversity of presenting characteristics that could be addressed by treatment [6, 7].

Proximal [8–11], distal [12] and local [13, 14] interventions have all demonstrated favourable PFP treatment outcomes. Multimodal physiotherapy, including a combination of patella taping, vasti retraining, gluteal strengthening, patella mobilisation and stretches, remains the gold standard treatment option with the strongest reported evidence base [15]. Considering the multifactorial nature of PFP, greater intervention efficacy could be achieved through better selection of treatment for a given patient, therefore improving clinical outcomes and future research. Furthermore, identification of outcome predictors that guide tailored intervention packages may reduce recurrence, known to be high [16, 17].

It is important to consider overall prognosis differently from outcome prediction. For example, a retrospective analysis of two high-quality (HQ), randomised controlled trials (RCTs) described the characteristics of the 55 % of individuals with PFP who had unfavourable overall outcome from multimodal packages of care at 3 months and 40 % at 12 months [18]. This prognostic analysis would not guide clinicians' specific intervention choice as a function of positive outcome. Evaluating outcome predictors to identify subgroups likely to respond to specific interventions has therefore received increased attention in the literature in recent years [19–32]. Consequently, the aim of this review was to identify potential outcome predictors for conservative interventions in the management of PFP in order to guide clinicians when considering the likelihood of intervention success and steer the direction of future research in this area.

2 Methods

2.1 Inclusion and Exclusion Criteria

Eligibility criteria were modified from a published review of musculoskeletal clinical prediction rules [33]. These included peer-reviewed journal publication, the primary study aim being development or evaluation of outcome predictors, application to treatment selection for patients with PFP, and clear evidence that the measurement tool was appropriate to the evaluated outcome predictor (e.g. use of the Kujala pain questionnaire as an outcome measure for individuals with PFP [34]). Unpublished work was not sought. Only papers published in English were considered.

2.2 Search Strategy

The AMED, CINAHL, EMBASE, MEDLINE and Web of Science databases were searched from inception up to April 2013. The keyword 'predict*.ti ab.' was used in combination with keywords relating to PFP to capture papers relating to the development of clinical prediction rules. The search criteria were modified from a previous PFP systematic review that evaluated the scope and quality of systematic reviews on non-pharmacological conservative treatment for PFP [35]. The search strategy and results are reported in the electronic supplementary material (ESM) Table S1. Citing, and cited, references were surveyed in Google scholar and at source, respectively.

2.3 Review Process

All titles and abstracts found were downloaded into Endnote X4 (Thomson Reuters, Philadelphia, PA, USA), search returns collated and duplicates removed. Potential papers were assessed by two independent reviewers (SL and CB) using an inclusion criteria checklist. If sufficient information could not be obtained from the title and abstract, the full text was obtained for further evaluation. Any disagreements were resolved by consensus, and a third reviewer (DM) was available if needed, but was not required.

2.4 Quality Assessment of Reviews

Methodological quality was assessed with a scale (ESM Table S2) used previously for a PFP systematic review [36], and applied by two reviewers independently (SL and CB), with discrepancies resolved by discussion, and a third reviewer (DM) was available if required. The quality assessment scale consisted of 19 items divided into four components—participants, interventions, outcome measures and data presentations. With RCTs considered the gold standard of predictor analysis, the scale is scored out of 40, with the total possible score given as a percentage. Scores ≥70 % were considered to be 'high quality' and scores <70 % considered to be 'low quality'.

2.5 Data Extraction and Analysis

Study design characteristics were extracted and tabulated to enable methodological comparison (Table 1). Treatment 'success' was defined within eight studies [19–23, 28, 30, 32], and not defined in a further six studies [24–27, 29, 31]. In studies where 'success' was defined, continuous and dichotomous baseline outcome predictor data for both 'successful' and 'unsuccessful' subgroups was extracted to allow univariate statistical analysis of effect size (ES) [standardised mean difference] and risk ratio calculations, respectively, using Review Manager (RevMan v5.1, 2011, The Cochrane Collaboration, Copenhagen, Denmark). ES and the associated 95 % confidence intervals (CIs) were presented as forest plots to facilitate visual comparison. Where two or more outcome predictors and success determinants were consistent between studies, data was pooled. Pooled results were reported as significant when the test for overall effect (Z score) was $p < 0.05$, and as a trend when $p < 0.1$. Determinants of success were considered consistent if a justified, clinically meaningful measure was used in the two or more studies pooled (e.g. 'Marked improvement' on a 5-point Likert scale). If adequate data was not available to complete calculations from published reports, attempts were made to contact corresponding authors. Where treatment success was not defined, baseline measures of potential outcome predictors reported to significantly predict change of the primary outcome through multivariate statistical analysis, were extracted. The primary outcome used for each study is presented in Table 1.

Interpretation of calculated individual or pooled ES were categorised based on those used by Hume et al. [37] as small (≤0.59), medium (0.60–1.19), or large (≥1.20). The level of statistical heterogeneity, defined as $p < 0.05$, for pooled data was established using the Chi-square and I^2 statistics. Definitions for 'levels of evidence' were guided by recommendations made by van Tulder et al. [38].

Strong evidence = pooled results derived from three or more studies, including a minimum of two HQ studies, which are statistically *homogenous* ($p > 0.05$)—may be associated with a statistically significant or non-significant pooled result.

Moderate evidence = statistically significant pooled results derived from multiple studies, including at least one HQ study, which are statistically *heterogeneous* ($p < 0.05$), or from multiple LQ studies which are statistically homogenous ($p > 0.05$).

Limited evidence = results from multiple LQ studies which are statistically *heterogeneous* ($p < 0.05$), or from one HQ study.

Very limited evidence = results from one LQ study.

Conflicting evidence = pooled results insignificant and derived from multiple studies, regardless of quality, which are statistically heterogeneous ($p < 0.05$, i.e. inconsistent).

3 Results

3.1 Review Selection and Identification

The initial search yielded 1,888 citations. Following application of the inclusion/exclusion criteria to citation title, abstract and full text, 15 cohort studies remained

Table 1 Study design characteristics for each included study

Study	Sample size	Treatment	No. of variables tested	Statistical analysis used for prediction	Outcome measures	Success defined Y/N	Determinant of success	Length of follow-up	Significant predictors of intervention success
Kannus and Niittymaki [31]	49	Rest NSAIDs Quadriceps strength For 6/52	22	Forward stepping regression analysis	VAS Lysholm Tegner	N	NA	6 weeks and 6 months	Younger age at both 6 weeks and 6 months
Natri et al. [26]	49	Rest NSAIDs Quadriceps strength For 6/52	19	Forward stepping regression analysis	VAS Lysholm Tegner	N	NA	7 years	Negative patellar apprehension test
Witvrouw et al. [27]	30	Seated leg press 2/1 knee bends Stationary bike Rowing machine Step up and down Progressive jumping For 5/52	13	Multiple stepwise regression analysis	Kujala	N	NA	5 weeks and 3 months	Faster reflex response time vastus medialis oblique Shorter duration of symptoms
Selfe et al. [29]	77 (60 at 3/12)	Stretching Vastus medialis training Patella taping/biofeedback 7 sessions	1	Analysis of covariance	Critical angle knee flexion Angular velocity knee flexion Treadmill test Modified Functional Index Questionnaire	N	NA	3 months	Not self-reporting ‘cold legs’
Sutlive et al. [23]	45	21/7 of pre-fabricated orthoses use Limitation of physical activity	14	Sensitivity, specificity and likelihood ratios (>2.0)	VAS GRCQ	Y	≥50 % improvement VAS	20–23 days	Forefoot alignment (2° or more valgus) Passive great toe extension (78° or less) Navicular drop (3 mm or less)
Lesher et al. [22]	50	Patella taping Immediate effect	19	Sensitivity, specificity and likelihood ratios	NPRS GRCQ	Y	≥50 % improvement mean NPRS or ≥+4 GRC	0 days	Tibial angulation (>5° varum) Ankle dorsiflexion knee flexed (≤15°) Positive patellar tilt Relaxed calcaneal stance (>4° varus)
Iverson et al. [21]	49	Lumbopelvic manipulation	43	Sensitivity, specificity and likelihood ratios	NPRS GRCQ	Y	≥50 % improvement NPRS or ≥+4 GRC	0 days	Difference in hip IR (>14°) Ankle dorsiflexion knee flexed (>16°) Navicular drop (>3 mm) No stiffness sitting >20 mins Squatting most painful activity

Table 1 continued

Study	Sample size	Treatment	No. of variables tested	Statistical analysis used for prediction	Outcome measures	Success defined Y/N	Determinant of success	Length of follow-up	Significant predictors of intervention success
Wittstein et al. [28]	30	Quadriceps, hip abduction, hip external rotation and core strengthening Quadriceps, hamstring and iliotibial band stretching For 8 weeks	4	Sensitivity, specificity and likelihood ratios	Patient seeking further treatment	Y	Complete resolution of symptoms at follow-up	2 months	No evidence of chondromalacia Patella Tibial tubercle deviation <14.6 mm
Piva et al. [24]	51	Quadriceps strengthening Quadriceps, hamstring and calf stretches Taping For 8 weeks	14	Multiple forward regression analysis	Activity of daily living scale of the knee outcome survey NPRS	N	NA	8 weeks	Positive change in fear avoidance beliefs
Vicenzino et al. [19]	42	Prefabricated foot orthoses 12 weeks	16	Sensitivity, specificity and likelihood ratios	5-point Likert scale	Y	'Marked improvement' on Likert scale	12 weeks	Age (>25 years) Height (<165 cm) Worst pain (<53.25 mm) Mid-foot width diff (>10.96 mm)
Lan et al. [30]	100	Patella taping	9	Multivariate logistic regression analysis	VAS	Y	'Marked improvement' on Likert scale	0 days	Lower body mass index Smaller mean lateral patellofemoral angle Larger mean quadriceps angle
Barton et al. [20]	60	Prefabricated foot orthoses For 12 weeks	15	Sensitivity, specificity and likelihood ratios	5-point Likert scale	Y	'Marked improvement' on Likert scale	12 weeks	Footwear motion control properties [<5 (less supportive)] Usual pain (<22 mm) Ankle dorsiflexion knee bent (<41.3°) Immediately reduced pain during single-leg squat with orthoses
Barton et al. [32]	26	Prefabricated foot orthoses For 12 weeks	12	Discriminant analysis	5-point Likert scale	Y	'Marked improvement' on Likert scale	12 weeks	Greater peak rearfoot eversion relative to the laboratory
Pattyn et al. [25]	36	Tailored strengthening, stretching and mobilisation For 7 weeks	26	Linear regression model	Kujala	N	NA	7 weeks	Cross-sectional area total quadriceps at mid-thigh level Eccentric average peak torque quadriceps at 60/s Frequency of pain

Table 1 continued

Study	Sample size	Treatment	No. of variables tested	Statistical analysis used for prediction	Outcome measures	Success defined Y/N	Determinant of success	Length of follow-up	Significant predictors of intervention success
Crowell et al. [41]	44	Lumbopelvic manipulation	5	Sensitivity, specificity and likelihood ratios	NPRS	Y	≥50 % improvement NPRS or ≥+4 GRC	0 days	Nil

NSAIDs non-steroidal anti-inflammatory drugs, *GRCQ* Global Rating of Change Questionnaire, *NPRS* Numeric Pain Rating Scale, *VAS* visual analogue scale, *Y* yes, *N* no, *NA* not assessed, *GRC* global rating of change, *IR* internal rotation

(Fig. 1). No RCTs were found. Two studies included data from the same PFP population [26, 31], however they reported findings from different follow-up durations and were both therefore included in the review. Two further studies, one that presented short- and long-term predictors of outcome without differentiating predictors for specific interventions [39], and the other that reported post hoc baseline foot mobility measures [40], could not be used within this review.

3.2 Additional Data

Additional data required for ES calculation was provided by authors for one paper [19].

3.3 Quality Assessment

Results from the quality assessment scale are shown in the ESM Table S2. Scores ranged from 15 to 24 out of a possible 40. Of the 15 included studies, all were scored as LQ.

3.4 Summary of Findings

3.4.1 Pain

Very limited evidence identified higher baseline functional index questionnaire scores (mean 0.82, 95 % CI 0.18–1.46) predicted improved outcome following 12-week orthoses intervention in one LQ study [19]. Pooled results from two LQ studies [19, 20] showed a trend towards less usual (mean −0.45, 95 % CI −0.93 to 0.03, $p = 0.07$) and worst pain (mean −0.45, 95 % CI −0.93 to 0.03, $p = 0.07$) being associated with foot orthoses success (Fig. 2).

Multiple stepwise regression identified shorter symptom duration predicted positive changes in Kujala scores associated with successful exercise intervention in one LQ study at 5-week and 3-month follow-up ($p = 0.045$ and $p = 0.019$, respectively) [27]. Lower frequency of pain at baseline, when identified with concurrent greater quadriceps cross-sectional area (CSA) and reduced eccentric quadriceps torque (see Sect. 3.4.3), was predictive of successful outcome after a quadriceps exercise programme combined with patella mobilisation and lower-limb stretches tailored to the individuals mobility/flexibility restrictions ($p = 0.012$) in one LQ study [25].

Very limited evidence indicated greater usual pain (mean 0.43, 95 % CI 0.01–0.85) significantly predicted taping intervention success in one LQ study [30].

3.4.2 Demographics

Limited evidence showed patient height (mean −0.17, 95 % CI −0.60 to 0.27, $p = 0.45$) and weight (mean −0.09, 95 % CI −0.52 to 0.34, $p = 0.68$) did not predict foot orthoses intervention success [19, 20]. Pooled results from three LQ studies [19, 20, 23] showed a trend for older age to predict successful outcomes from foot orthoses intervention (mean 0.29, 95 % CI −0.06 to 0.65, $p = 0.1$) (Fig. 3).

Younger age predicted positive changes in pain (decreased visual analogue scale score), Tegner and Lysholm scores at 6 weeks, and Tegner and Lysholm scores at 6 months' follow-up after exercise intervention [31].

3.4.3 Knee

No local knee characteristics were shown to predict foot orthoses intervention success (Fig. 4).

Faster vastus medialis oblique (VMO) reflex response time ($p = 0.041$ and $p = 0.026$, respectively) predicted positive changes in Kujala scores following exercise intervention [27]. Multiple stepwise regression (forward stepping) identified negative patella apprehension at baseline to predict positive changes in Tegner and Lysholm scores at 7-year follow-up in one LQ exercise intervention study [26]. An absence of chrondomalacia patella and tibial tubercle deviation <14.6 mm on magnetic resonance imaging (MRI) predicted resolution of symptoms at 5 weeks following exercise intervention in one LQ study [27]. A further LQ exercise intervention study identified a lack of self-reported 'cold legs' ($p = 0.019$) predicted delayed onset of pain during a treadmill test [29]. Single variables added to a linear regression model identified greater CSA of the total quadriceps at mid-thigh level ($p = 0.01$) and reduced eccentric average quadriceps peak torque at 60°/s

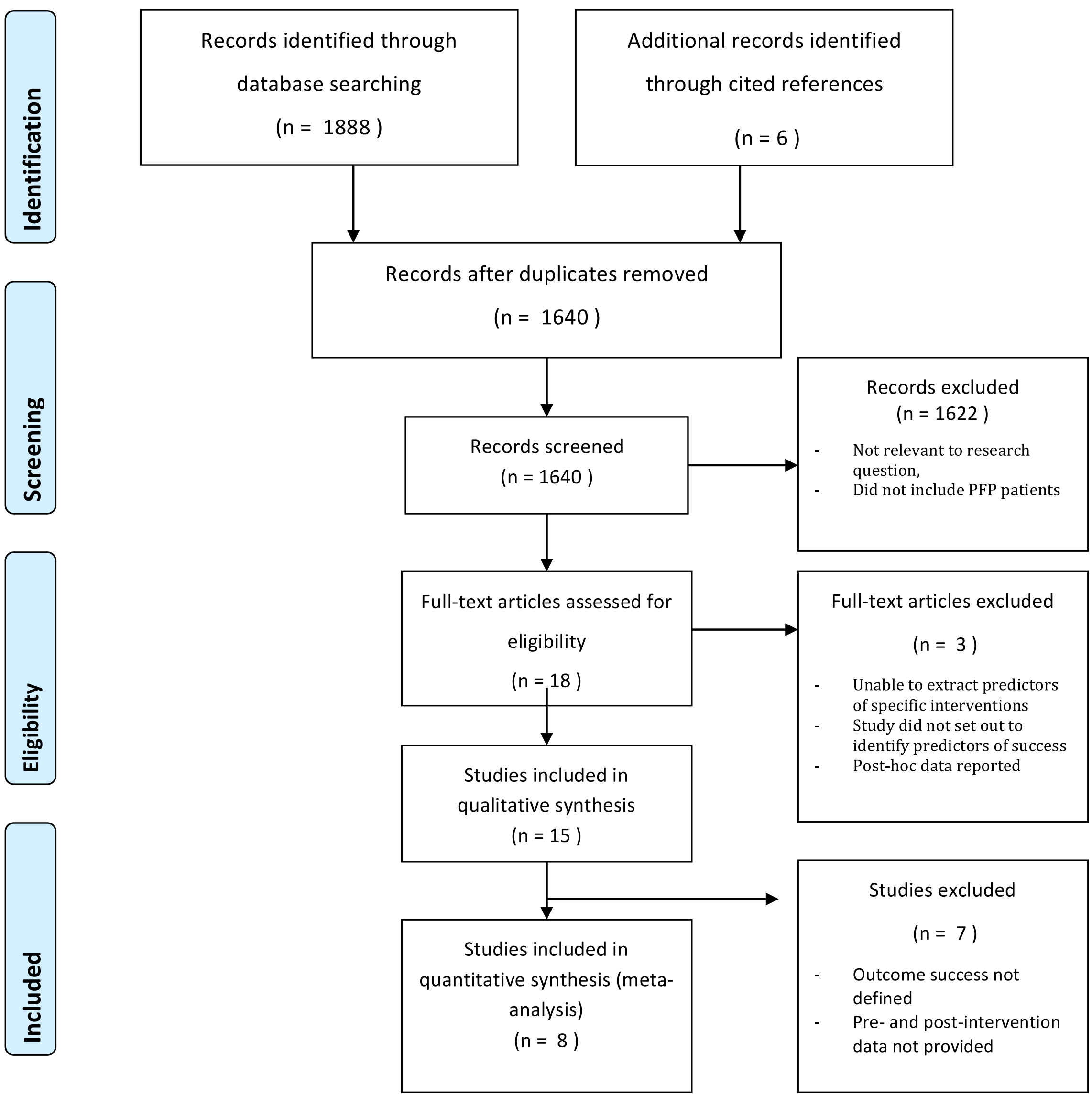

Fig. 1 Flow diagram summarising study selection for inclusion. *PFP* patellofemoral pain

($p = 0.015$) at baseline as predictors of successful outcome, when identified with concurrent lower frequency of pain (see Sect. 3.4.1), after a tailored exercise and mobilisation programme in one LQ study [25].

Limited evidence indicated an increased Q-angle was a significant predictor of a successful outcome following patellar taping intervention (two LQ studies [22, 40], mean 0.38, 95 % CI 0.05–0.72, $p = 0.03$) [Fig. 4]. Very limited evidence identified reduced lateral patellofemoral angle (LPA) [mean −0.47, 95 % CI −0.89 to −0.05] predicted patellar taping success [30].

Most pain squatting (mean 2.27, 95 % CI 1.57–3.28), greater patella glide (mean 1.59, 95 % CI 1.18–2.26), less stiffness (mean 0.43, 95 % CI 0.3–0.61) and fewer episodes of giving way (mean 0.65, 95 % CI 0.49–0.86) and clicking (mean 0.64, 95 % CI 0.47–0.88) were shown to be significant predictors of lumbopelvic manipulation success [21]; however, these findings were not replicated in a follow-up study using the methodological design [41].

3.4.4 Hip and Pelvis

No significant predictors at the hip or pelvis for foot orthoses, exercise, patellar taping or lumbopelvic manipulation were identified (Fig. 5).

3.4.5 Foot and Ankle

Limited evidence showed great toe extension (mean −0.16, 95 % CI −0.59 to 0.27, $p = 0.46$) and ankle dorsiflexion range with the knee bent (mean −0.25, 95 % CI −0.68 to 0.18) did not significantly predict orthoses success [20, 23]. Very limited evidence reported greater forefoot valgus (mean 0.67, 95 % CI 0.05–1.28) predicted successful outcomes following 20–23 days of wearing prescribed prefabricated foot orthoses in one LQ study [23]. Greater rearfoot eversion magnitude peak predicted orthoses intervention success (mean −0.93, 95 % CI −1.84 to −0.01) in one LQ study [32] (Fig. 6).

4 Discussion

The intent of this review was to identify outcome predictors for specific conservative interventions in the management of PFP in order to guide clinicians when considering the likelihood of intervention success. With an absence of RCTs prospectively validating outcome predictors, significant findings should only be considered as preliminary indicators of successful outcome prediction. Additionally, the potential for this review to categorically differentiate between predictors of success following specific

Study or Subgroup	Successful group Mean	SD	Total	Unsuccessful group Mean	SD	Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Lumbar Manipulation								
Duration (Iverson 2008)	52.6	75.4	22	129.4	248.4	27	8.0%	−0.39 [−0.96, 0.17]
Foot Orthoses								
AKP Sc (Vicenzino 2010)	73.9	9.1	17	69.3	8.7	25	6.6%	0.51 [−0.12, 1.14]
FIQ Sc (Vicenzino 2010)	10.9	1.2	17	9.4	2.1	25	6.3%	0.82 [0.18, 1.46]
SDatBase (Barton 2011A)	13.5	8.5	14	12.2	9.3	43	7.1%	0.14 [−0.46, 0.74]
SLRsitbase (Barton 2011A)	7.3	7.1	14	7.4	7.1	43	7.2%	−0.01 [−0.62, 0.59]
Duration (Barton 2011A)	64	51	14	70	61	14	4.7%	−0.10 [−0.84, 0.64]
Duration (Sutlive 2004)	177.4	209.3	27	167.4	159.4	18	7.3%	0.05 [−0.55, 0.65]
Duration (Vicenzino 2010)	65.47	66.68	17	55.25	42.85	25	6.8%	0.19 [−0.43, 0.80]
Subtotal (95% CI)			**58**			**57**	**18.9%**	**0.06 [−0.31, 0.43]**
Heterogeneity: Chi² = 0.35, df = 2 (P = 0.84); I² = 0%								
Test for overall effect: Z = 0.32 (P = 0.75)								
U.P. (Barton 2011A)	26.9	25.3	14	36.1	19	14	4.6%	−0.40 [−1.15, 0.35]
U.P. (Vicenzino 2010)	34	13.6	17	41.6	16.7	25	6.7%	−0.48 [−1.11, 0.15]
Subtotal (95% CI)			**31**			**39**	**11.3%**	**−0.45 [−0.93, 0.03]**
Heterogeneity: Chi² = 0.03, df = 1 (P = 0.87); I² = 0%								
Test for overall effect: Z = 1.82 (P = 0.07)								
W.P. (Barton 2011A)	52.4	19.2	14	55.6	18.6	14	4.7%	−0.16 [−0.91, 0.58]
W.P. (Vicenzino 2010)	52.8	11.4	17	63	17.2	25	6.5%	−0.66 [−1.29, −0.03]
Subtotal (95% CI)			**31**			**39**	**11.2%**	**−0.45 [−0.93, 0.03]**
Heterogeneity: Chi² = 0.99, df = 1 (P = 0.32); I² = 0%								
Test for overall effect: Z = 1.84 (P = 0.07)								
Taping								
Duration (Lesher 2006)	9.6	16	26	12	19.6	24	8.4%	−0.13 [−0.69, 0.42]
U.P. (Lan 2010)	51.7	17.8	66	43.8	18.7	34	14.9%	0.43 [0.01, 0.85]

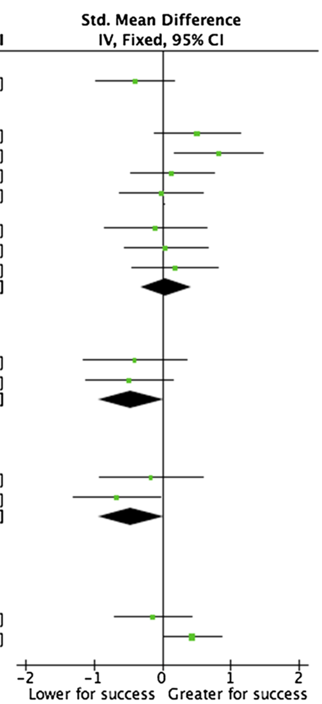

Fig. 2 Baseline pain characteristics for 'successful' and 'unsuccessful' groups following lumbopelvic manipulation, foot orthoses and taping interventions. *AKP Sc* anterior knee pain score, *FIQ Sc* functional index questionnaire score, *SDatBase* step-down at baseline, *SLRsitbase* single-leg rises from sitting at baseline, *U.P.* usual pain, *W.P.* worst pain, *SD* standard deviation, *IV* inverse variance, *CI* confidence interval, *df* degrees of freedom. Barton 2011a [20], Barton 2011b [32]

Study or Subgroup	Successful group Mean	SD	Total	Unsuccessful group Mean	SD	Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Lumbar Manipulation								
Age (Iverson 2008)	25.3	7.1	22	23.9	6.7	27	6.0%	0.20 [−0.36, 0.76]
Foot Orthoses								
BMI (Vicenzino 2010)	25.5	4.3	17	26	6.4	25	5.0%	−0.09 [−0.70, 0.53]
Age (Barton 2011A)	26	5	14	26	5	43	5.2%	0.00 [−0.60, 0.60]
Age (Sutlive 2004)	29.1	6.3	27	27.5	4.8	18	5.3%	0.27 [−0.33, 0.87]
Age (Vicenzino 2010)	30	5.1	17	26.5	5.5	25	4.8%	0.64 [0.01, 1.28]
Subtotal (95% CI)			**58**			**86**	**15.3%**	**0.29 [−0.06, 0.65]**
Heterogeneity: $Chi^2 = 2.08$, df = 2 (P = 0.35); $I^2 = 4\%$								
Test for overall effect: Z = 1.64 (P = 0.10)								
Height (Barton 2011A)	1.7	0.1	14	1.69	0.08	43	5.2%	0.12 [−0.49, 0.72]
Height (Vicenzino 2010)	169.8	7.5	17	174.1	9.9	25	4.9%	−0.47 [−1.09, 0.16]
Subtotal (95% CI)			**31**			**68**	**10.1%**	**−0.17 [−0.60, 0.27]**
Heterogeneity: $Chi^2 = 1.73$, df = 1 (P = 0.19); $I^2 = 42\%$								
Test for overall effect: Z = 0.75 (P = 0.45)								
Weight (Barton 2011A)	68	8	14	67	13	43	5.2%	0.08 [−0.52, 0.69]
Weight (Vicenzino 2010)	73.8	15.5	17	79.5	22.9	25	5.0%	−0.28 [−0.90, 0.34]
Subtotal (95% CI)			**31**			**68**	**10.2%**	**−0.09 [−0.52, 0.34]**
Heterogeneity: $Chi^2 = 0.66$, df = 1 (P = 0.42); $I^2 = 0\%$								
Test for overall effect: Z = 0.42 (P = 0.68)								
Exercise								
Age (Wittstein 2009)	32.6	2.73	15	31.4	1.71	15	3.6%	0.51 [−0.22, 1.24]
Taping								
BMI (Lan 2010)	23	3.2	66	24.4	5	34	11.0%	−0.36 [−0.77, 0.06]
Height (Lan 2010)	1.62	0.09	66	1.65	0.07	34	11.0%	−0.36 [−0.77, 0.06]
Weight (Lan 2010)	61.4	12	66	66.8	15.9	34	10.9%	−0.40 [−0.82, 0.02]
Age (Lan 2010)	41.9	12.9	66	42	10.6	34	11.1%	−0.01 [−0.42, 0.41]
Age (Lesher 2006)	21.7	3.8	26	23.9	4.4	24	6.0%	−0.53 [−1.09, 0.04]
Subtotal (95% CI)			**92**			**58**	**17.1%**	**−0.19 [−0.52, 0.14]**
Heterogeneity: $Chi^2 = 2.12$, df = 1 (P = 0.15); $I^2 = 53\%$								
Test for overall effect: Z = 1.11 (P = 0.27)								

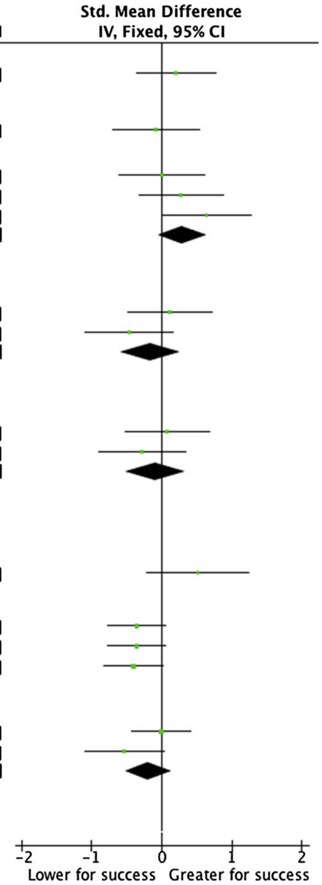

Fig. 3 Baseline demographic characteristics for 'successful' and 'unsuccessful' groups following lumbopelvic manipulation, foot orthoses, exercise and taping interventions. *BMI* body mass index, *SD* standard deviation, *IV* inverse variance, *CI* confidence interval, *df* degrees of freedom. Barton 2011a [20], Barton 2011b [32]

Study or Subgroup	Successful group Mean	SD	Total	Unsuccessful group Mean	SD	Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Lumbopelvic Manipulation								
Q angle (Iverson 2008)	12.4	6.7	22	11.5	4.6	27	7.1%	0.16 [−0.41, 0.72]
TibTor (Iverson 2008)	20.5	6.2	22	20.8	7.6	27	7.1%	−0.04 [−0.61, 0.52]
TibValgum (Iverson 2008)	−4.2	2.4	22	−3.4	1.9	27	6.9%	−0.37 [−0.94, 0.20]
Foot Orthoses								
Q angle (Sutlive 2004)	9.2	4.8	27	9.3	5.6	18	6.3%	−0.02 [−0.62, 0.58]
TibTor (Sutlive 2004)	28.1	7.1	27	26	7.9	18	6.2%	0.28 [−0.32, 0.88]
TibValgum (Sutlive 2004)	−5.4	3.7	27	−6.2	3.7	18	6.3%	0.21 [−0.39, 0.81]
Taping								
LPA (Lan 2010)	10.25	3.84	66	12	3.49	34	12.8%	−0.47 [−0.89, −0.05]
LPD (Lan 2010)	1.52	1.85	66	1.81	1.62	34	13.1%	−0.16 [−0.58, 0.25]
TibTor (Lesher 2006)	23.8	6.9	26	21.3	7.4	24	7.2%	0.34 [−0.21, 0.90]
TibValgum (Lesher 2006)	−2.5	5.8	26	−0.7	4.5	24	7.2%	−0.34 [−0.90, 0.22]
Q angle (Lan 2010)	25.23	5.62	66	22.32	5.07	34	12.7%	0.53 [0.11, 0.95]
Q angle (Lesher 2006)	15.8	5.4	26	15.1	6.3	24	7.3%	0.12 [−0.44, 0.67]
Subtotal (95% CI)			**92**			**58**	**19.9%**	**0.38 [0.05, 0.72]**
Heterogeneity: $Chi^2 = 1.35$, df = 1 (P = 0.25); $I^2 = 26\%$								
Test for overall effect: Z = 2.22 (P = 0.03)								

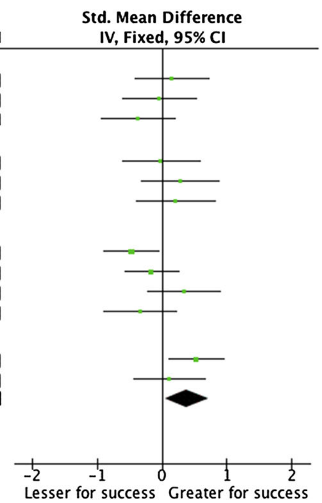

Fig. 4 Baseline knee characteristics for 'successful' and 'unsuccessful' groups following lumbopelvic manipulation, foot orthoses and taping interventions. *LPA* lateral patellofemoral angle, *LPD* lateral patellar displacement, *TibTor* tibial torsion, *TibValgum* tibial valgum, *SD* standard deviation, *IV* inverse variance, *CI* confidence interval, *df* degrees of freedom

interventions and indicators of the probable course of PFP symptoms (prognostic factors) is limited by an absence of control groups.

We identified evaluation of 205 conservative management outcome predictors within 15 LQ cohort studies. Of this comprehensive range, 19 (9 % of total) were found to be significant. Of the 15 included studies, none have reached the validation stage of prediction development important for ensuring predictors accurately identify individuals who will benefit from specific interventions [33]. We found all studies used a single-arm design, without the inclusion of a control group, and did not recruit adequate participants relative to the number of variables investigated [42]. Although this single-arm design can be a useful tool in the derivation stage of outcome prediction, it is not powerful enough to provide definitive information on factors that can modify treatment effects. As such, the outcome predictors identified in these studies have a high risk of being non-specific predictors of outcome—that is, predictive of outcome regardless of management care plan rather than response to specific interventions—or prognostic factors [33]. Variability in outcome measures and follow-up duration was evident across the included studies, further limiting evidence synthesis and therefore the strength of conclusions drawn.

4.1 Potential Predictors

4.1.1 Pain

Higher functional index questionnaire scores [19] and a trend towards less 'usual' and less 'worst' pain [19, 20] predicting orthoses intervention success suggest that lower symptom severity may be predictive of a favourable outcome. Similar findings were also evident following exercise intervention, with shorter symptom duration [27] and lower frequency of pain [25] predicting better outcomes. When compared with a multicentre PFP prognostic study showing symptom duration over 2 months and Anterior Knee Pain Scale score less than 70/100 (more severe symptoms) predicted poor outcomes [18], the findings from this review further implicate pain variables as prognostic factors irrespective of orthoses or exercise intervention. Of interest, higher pain severity at baseline and longer pain duration have also shown association with poor prognosis in other musculoskeletal pain conditions [43]. Irrespective of being predictive or prognostic, these findings highlight the clinical importance of implementing an effective intervention programme early in the pain experience in order to increase the likelihood of intervention success and reduce the risk of chronicity.

In contrast, greater usual pain was identified within one LQ study to be predictive of patellar taping success (mean 0.43, 95 % CI 0.01–0.85) [40]. The most significant limitation of these findings is that only immediate effects were assessed. With literature pertaining to the mechanisms and effect of taping beyond the short-term being limited [13], the strength of clinical inference for this predictor is somewhat limited. Further research exploring longer-term taping efficacy and the ability of greater usual pain to predict its outcome is needed.

4.1.2 Demographics

Consistent with prognosis following physiotherapy intervention including foot orthoses application [39], limited evidence showed patient height and weight was not predictive of a successful outcome following foot orthoses intervention [19, 20]. In contrast with prognostic data, a trend towards older age was identified as a predictor of foot orthoses success [20, 23], and younger age significantly predictive of exercise intervention success [31]. There are many plausible explanations for both of these results, primarily speculative in nature. First, movement patterns may be more entrenched in older individuals requiring an external adjunct to facilitate changes that can lead to symptom reduction. Second, younger individuals with pain may have a greater capacity for muscular adaptation—both neuromuscular adaptation and strength development—

Study or Subgroup	Successful group Mean	SD	Total	Unsuccessful group Mean	SD	Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Lumbar Manipulation								
Craig's (Iverson 2008)	12.7	5.2	22	13.2	5	27	14.7%	−0.10 [−0.66, 0.47]
Hip IR (Iverson 2008)	41.3	40.2	22	44.4	10.8	27	14.7%	−0.11 [−0.67, 0.45]
Hip IR Dif (Iverson 2008)	10.2	7.9	22	8.4	5.2	27	14.6%	0.27 [−0.30, 0.84]
Pel. Crest (Iverson 2008)	−0.1	0.6	22	0.01	0.6	27	14.7%	−0.18 [−0.74, 0.38]
Foot Orthoses								
Craig's (Sutlive 2004)	13	7.4	27	10.7	12.2	18	13.0%	0.24 [−0.36, 0.83]
LL Diff (Sutlive 2004)	7.6	7.4	27	6.8	5.9	18	13.1%	0.11 [−0.48, 0.71]
Taping								
Craig's (Lesher 2006)	7.9	20.5	26	6.4	9.7	24	15.2%	0.09 [−0.46, 0.65]

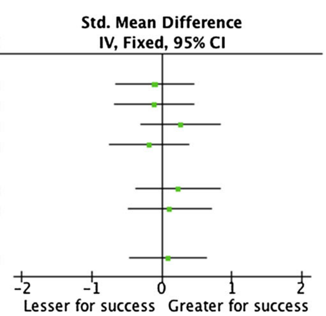

Fig. 5 Baseline hip characteristics for 'successful' and 'unsuccessful' groups following lumbopelvic manipulation, foot orthoses and taping interventions. *Craig's* Craig's test, *Hip IR* hip internal rotation range, *Hip IR Diff* hip internal rotation range difference, *Pel. Crest* pelvic crest height, *LL Diff* leg-length difference, *SD* standard deviation, *IV* inverse variance, *CI* confidence interval

Study or Subgroup	Successful group Mean	SD	Total	Unsuccessful group Mean	SD	Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Lumbopelvic Manipulation								
A.df/KE (Iverson 2008)	6.3	3.3	22	6	4.4	27	3.1%	0.07 [−0.49, 0.64]
A.df/KF (Iverson 2008)	17.1	5.1	22	15.1	6.7	27	3.0%	0.33 [−0.24, 0.89]
Calc St (Iverson 2008)	−5.4	3.1	22	−7.3	3.4	27	2.9%	0.57 [−0.00, 1.15]
FF align (Iverson 2008)	−3.5	1.9	22	−3.6	1.6	27	3.1%	0.06 [−0.51, 0.62]
Gt Toe Ex (Iverson 2008)	91.4	13.6	22	91.3	11.4	27	3.1%	0.01 [−0.56, 0.57]
Nav Drop (Iverson 2008)	4	3.7	22	3	3	27	3.0%	0.30 [−0.27, 0.86]
STJN NWB (Iverson 2008)	−3	1.8	22	−3.5	1.9	27	3.0%	0.27 [−0.30, 0.83]
Foot Orthoses (static foot)								
AchHght (Vicenzino 2010)	−64.4	8.3	17	−68.2	6.7	25	2.5%	0.51 [−0.12, 1.13]
Calc St (Sutlive 2004)	−5.7	4	27	−8.1	4.9	18	2.6%	0.54 [−0.07, 1.15]
FF align (Sutlive 2004)	−4.9	7.3	27	−10.2	8.5	18	2.6%	0.67 [0.05, 1.28]
FPI (Barton 2011A)	2.9	3	14	3.5	3.2	43	2.7%	−0.19 [−0.79, 0.42]
MFW NWB (Vicenzino 2010)	74.1	7.4	17	75.7	7.5	25	2.5%	−0.21 [−0.83, 0.41]
MFW WB (Vicenzino 2010)	85.3	9.7	17	84.5	10.4	25	2.6%	0.08 [−0.54, 0.69]
RF STJN (Sutlive 2004)	−8.1	5.5	27	−8.2	6.2	18	2.7%	0.02 [−0.58, 0.61]
Foot Orthoses (foot mobility)								
AH Rat (Vicenzino 2010)	−0.338	0.029	17	−0.357	0.032	25	2.4%	0.60 [−0.03, 1.24]
MFW Dif (Vicenzino 2010)	11.1	4.8	17	8.8	3.6	25	2.5%	0.55 [−0.08, 1.18]
Nav Drop (Sutlive 2004)	3.6	3.1	27	6.3	4.9	18	2.6%	−0.68 [−1.29, −0.06]
NNav Drop (Barton 2011A)	1.72	1.7	14	2.33	1.95	43	2.7%	−0.32 [−0.92, 0.29]
Foot Orthoses (saggital plane mobility)								
A.df/KE (Sutlive 2004)	7.3	4	27	8.1	5.8	18	2.7%	−0.16 [−0.76, 0.43]
A.df/KF (Barton 2011A)	40.1	13.2	14	45.2	6	43	2.6%	−0.61 [−1.22, 0.01]
A.df/KF (Sutlive 2004)	21.3	7.1	27	20.7	7.4	18	2.7%	0.08 [−0.52, 0.68]
Subtotal (95% CI)			**41**			**61**	**5.3%**	**−0.25 [−0.68, 0.18]**
Heterogeneity: Chi² = 2.49, df = 1 (P = 0.11); I² = 60%								
Test for overall effect: Z = 1.16 (P = 0.25)								
Gt Toe Ex (Barton 2011A)	55.1	9.4	14	53.5	12.4	43	2.7%	0.13 [−0.47, 0.74]
Gt Toe Ex (Sutlive 2004)	92.8	11.9	27	98.5	12.7	18	2.7%	−0.46 [−1.06, 0.15]
Subtotal (95% CI)			**41**			**61**	**5.3%**	**−0.16 [−0.59, 0.27]**
Heterogeneity: Chi² = 1.85, df = 1 (P = 0.17); I² = 46%								
Test for overall effect: Z = 0.74 (P = 0.46)								
Foot Orthoses (dynamic foot function)								
FFRFABMP (Barton 2011B)	3	7.5	7	−0.8	7.4	18	1.2%	0.49 [−0.39, 1.38]
FFRFABROM (Barton 2011AB)	7.3	2.5	7	7.5	2.6	18	1.3%	−0.08 [−0.95, 0.80]
FFRFABTP (Barton 2011B)	39.2	8.8	7	41.2	11.6	18	1.3%	−0.18 [−1.05, 0.70]
FFRFDFMP (Barton 2011B)	14.1	5.2	7	11.3	5.1	18	1.2%	0.53 [−0.36, 1.42]
FFRFDFROM (Barton 2011B)	7.9	0.9	7	7.9	2.5	18	1.3%	0.00 [−0.87, 0.87]
FFRFDFTP (Barton 2011B)	51.8	2.6	7	51	2.5	18	1.3%	0.31 [−0.57, 1.18]
RFLABEVMP (Barton 2011B)	−5.4	2.1	7	−3.1	2.5	18	1.2%	−0.93 [−1.84, −0.01]
RFLABEVROM (Barton 2011B)	5.2	1.2	7	6	1.8	18	1.2%	−0.46 [−1.35, 0.42]
RFLABEVTP (Barton 2011B)	29.6	6.6	7	32	6	18	1.3%	−0.38 [−1.26, 0.50]
RFTIBEVMP (Barton 2011B)	−8.7	3.1	7	−7.6	3	18	1.3%	−0.35 [−1.23, 0.53]
RFTIBEVROM (Barton 2011B)	9	1.7	7	9.5	3.1	18	1.3%	−0.17 [−1.05, 0.70]
RFTIBEVTP (Barton 2011B)	34.4	4.2	7	32.3	6.5	18	1.3%	0.34 [−0.54, 1.22]
Taping								
A.df/KE (Lesher 2006)	9.6	5.6	26	11	6.6	24	3.1%	−0.23 [−0.78, 0.33]
A.df/KF (Lesher 2006)	20.7	20.7	26	16.3	6	24	3.1%	0.28 [−0.28, 0.84]
Calc St (Lesher 2006)	−1.8	9.2	26	2	7.7	24	3.1%	−0.44 [−1.00, 0.12]
FF align (Lesher 2006)	−4.8	6.9	26	−2.7	6.6	24	3.1%	−0.31 [−0.86, 0.25]
Gt Toe Ex (Lesher 2006)	76.2	20.5	26	77.2	22.2	24	3.2%	−0.05 [−0.60, 0.51]
Nav drop (Lesher 2006)	5.4	3.6	26	5.3	3.2	24	3.2%	0.03 [−0.53, 0.58]
RF STJN (Lesher 2006)	−2.8	8.5	26	−2.7	7.3	24	3.2%	−0.01 [−0.57, 0.54]

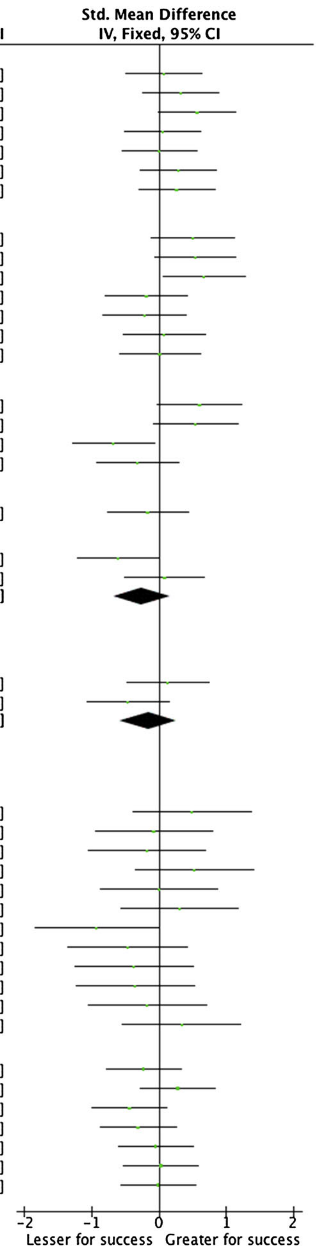

Fig. 6 Baseline foot and ankle characteristics for 'successful' and 'unsuccessful' groups following lumbopelvic manipulation, foot orthoses and taping interventions. *A.df/KE* ankle DF with knee extended, *A.df/KF* ankle DF with knee flexed, *CalcSt* relaxed calcaneal stance, *FFalign* forefoot alignment, *GtToeEx* great toe extension, *NavDrop* navicular drop, *RF STJN* rearfoot in subtalar joint neutral position, *MFW WB* mid-foot width (weight-bearing), *MFW NWB* mid-foot width (non-weight-bearing), *MFW Dif* mid-foot width difference (MFW WB−MFW NWB), *AchHght* arch height, *AH Rat* arch height ration, *STJN NWB* subtalar joint neutral non-weight-bearing, *RF.TIB.EV.MP* rearfoot relative to tibia eversion magnitude peak, *RF.TIB.EV.TP* rearfoot relative to tibia eversion timing to peak, *RF.TIB.EV.ROM* rearfoot relative to tibia eversion range of motion, *FF.RF.DF.MP* forefoot relative to rearfoot motion dorsiflexion magnitude peak, *FF.RF.DF.TP* forefoot relative to rearfoot motion dorsiflexion timing to peak, *FF.RF.DF.ROM* forefoot relative to rearfoot motion dorsiflexion range of motion, *FF.RF.AB.MP* forefoot relative to rearfoot motion abduction magnitude peak, *FF.RF.AB.TP* forefoot relative to rearfoot motion abduction timing peak, *FF.RF.AB.ROM* forefoot relative to rearfoot motion abduction range of motion, *RF.LAB.EV.MP* rearfoot relative to laboratory eversion magnitude peak, *RF.LAB.EV.TP* rearfoot relative to laboratory eversion timing peak, *RF.LAB.EV.ROM* rearfoot relative to laboratory eversion range of motion, *SD* standard deviation, *IV* inverse variance, *CI* confidence interval, *df* degrees of freedom. Barton 2011a [20], Barton 2011b [32]

following exercise intervention. Validation of demographic characteristics predicting orthoses and exercise intervention warrants further investigation; however, consideration of patient age in the clinical setting may be an important characteristic for determining foot orthoses or exercise intervention success.

4.1.3 Knee

To our knowledge, no prognostic studies have investigated clinical measures of the knee as predictors of outcome. The findings from this review identify derivation level indicators of outcome prediction that require validation using case-control study design. Some of the potential predictors require expensive equipment (MRI) or cannot be easily obtained within the clinic environment (VMO reflex response time), limiting applicability to all clinical settings. Identification of additional predictors of both exercise and patellar taping intervention success that can be easily applied within the clinical setting requires further work to ensure maximal clinical utility.

A lack of sound clinical evidence for the role of lumbopelvic manipulation in the management of PFP, when compared with foot orthoses, exercise and patellar taping, questions the suitability of this modality undergoing an outcome prediction derivation study. Furthermore, a subsequent single-arm cohort study reported none of the initially identified predictors for lumbopelvic manipulation success were predictive when the same methods were repeated [41]. Further good-quality case-control studies, exploring the effectiveness of this intervention within PFP populations should be sought prior to attempting to identify subgroups of individuals who may benefit.

4.1.4 Hip and Pelvis

The absence of significant indicators of prognosis or successful outcome prediction at the hip and pelvis highlights an area within the current literature where further research is clearly needed. The role of the hip and pelvis in PFP development [44] and maintenance of symptoms [7] has received significant attention within recent literature. Interventions focused at this area have also shown favourable outcomes [45]. Therefore, identification of predictors that can inform clinical reasoning concerning hip and pelvis treatment has the potential to significantly increase treatment efficacy.

4.1.5 Foot and Ankle

The presence of excessive foot pronation has traditionally formed the basis of foot orthoses prescription. Despite multiple measures of foot posture reported in this review, greater forefoot valgus (forefoot-to-rearfoot angle measured in subtalar joint neutral) [23] and peak rearfoot eversion relative to laboratory [32] were the only identified significant predictors of foot orthoses intervention success. Although unable to extract specific interventions on which the predictor was evaluated, Collins et al. [39] reported weight-bearing arch height did not significantly predict prognosis. Conversely, a change in mid-foot width has been identified in two studies to predict foot orthoses success [19, 46]. Vicenzino et al. [19] reported a mid-foot width difference from non-weight-bearing to weight-bearing >10.96 mm significantly predicted success when a significance level of $p < 0.20$ was used and in subsequent regression analysis. Similarly, Mills et al. [40] reported a difference in mid-foot width of >11.25 mm correctly predicted orthoses success in 7 of 10 individuals using a classification tree model. Variability in clinical measures prevents direct comparison between prognostic and predictor studies; however, considering dynamic rearfoot eversion has been identified as a potential predictor of foot orthoses success [32], there is clear merit for further exploration of dynamic foot posture measures in predicting orthoses intervention outcomes.

4.2 Future Directions

More robust study design, including the use of control groups, would permit stronger conclusions to be made about the predictive capacity of the variables measured and allow differentiation from prognostic factors. Future studies should aim to address this evidence gap.

Consistency between studies and researchers for determinants of treatment 'success' warrants development of consensus in future research. It is acknowledged that variability in the measure of success between studies can influence the significance of the findings presented in this review.

Further prediction studies for an evidence-based multimodal physiotherapy intervention [46] should be conducted given this approach is the gold standard of therapy management for PFP [15]. Although this may seem contradictory to attempting to deliver a more tailored intervention from the appropriate use of outcome predictors, a multimodal approach still yields poor long-term outcomes. Studies predicting individuals who do improve may help to identify subgroups that require a novel intervention approach.

Some of the predictors identified within this review required the use of expensive (MRI scanning), sometimes inaccessible (VMO reflex response and rearfoot eversion magnitude peak) equipment to administer within the clinic. To ensure maximal clinical utility of the outcome predictors investigated, future studies should aim to assess potential predictors that are easy to administer, take minimal time, are repeatable, and provide useful information that is relevant to the intervention.

Lastly, for outcome predictors to be accurately integrated into a clinically reasoned and tailored intervention approach, studies to progress the evidence base from derivation stage of design to validation level are clearly warranted.

5 Conclusion

This systematic review provides a contemporary summary of derivation level studies identifying indicators of prediction for conservative PFP management. Without quality randomised clinical trials to categorically prove any of these identified predictors, this review is unable to differentiate between predictors of success and prognostic factors. The identified indicators of prediction should be considered non-specific prognostic factors and need to undergo further investigation before being applied clinically with confidence. The findings from this review do however highlight important potential predictors, which can be cautiously applied within clinical reasoning paradigms, and give important direction for future research. With appropriate caution, clinicians should consider patellar taping for those with greater usual pain, foot orthoses for older individuals and exercise for younger individuals, and foot orthoses intervention for patients with greater forefoot valgus and rearfoot eversion magnitude peak. RCTs to validate indicators of prediction are clearly warranted to provide clinicians with robust evidence to deliver a tailored intervention to this heterogeneous patient population.

Acknowledgments No sources of funding were used to assist in the preparation of this review. Simon Lack, Christian Barton, Bill Vicenzino and Dylan Morrissey have no potential conflicts of interest that are directly relevant to the content of this review.

References

1. Baquie P, Brukner P. Injuries presenting to an Australian sports medicine centre: a 12-month study. Clin J Sport Med. 1997;7(1):28–31.
2. Taunton JE, Ryan MB, Clement DB, et al. A retrospective case-control analysis of 2002 running injuries. Br J Sports Med. 2002;36(2):95–101.
3. D'Hondt NE, Struijs PA, Kerkhoffs GM, et al. Orthotic devices for treating patellofemoral pain syndrome. Cochrane Database Syst Rev. 2002;(2):CD002267.
4. Powers CM, Bolgla LA, Callaghan MJ, et al. Patellofemoral pain: proximal, distal, and local factors, 2nd International Research Retreat. J Orthop Sports Phys Ther. 2012;42(6):A1–54.
5. Lankhorst NE, Bierma-Zeinstra SM, van Middelkoop M. Risk factors for patellofemoral pain syndrome: a systematic review. J Orthop Sports Phys Ther. 2012;42(2):81–94.
6. Pappas E, Wong-Tom WM. Prospective predictors of patellofemoral pain syndrome: a systematic review with meta-analysis. Sports Health. 2012;4(2):115–20.
7. Lankhorst NE, Bierma-Zeinstra SM, van Middelkoop M. Factors associated with patellofemoral pain syndrome: a systematic review. Br J Sports Med. 2013;47(4):193–206.
8. Khayambashi K, Mohammadkhani Z, Ghaznavi K, et al. The effects of isolated hip abductor and external rotator muscle strengthening on pain, health status, and hip strength in females with patellofemoral pain: a randomized controlled trial. J Orthop Sports Phys Ther. 2012;42(1):22–9.
9. Nakagawa TH, Muniz TB, Baldon Rde M, et al. The effect of additional strengthening of hip abductor and lateral rotator muscles in patellofemoral pain syndrome: a randomized controlled pilot study. Clin Rehabil. 2008;22(12):1051–60.
10. Fukuda TY, Melo WP, Zaffalon BM, et al. Hip posterolateral musculature strengthening in sedentary women with patellofemoral pain syndrome: a randomized controlled clinical trial with 1-year follow-up. J Orthop Sports Phys Ther. 2012;42(10):823–30.
11. Dolak KL, Silkman C, Medina McKeon J, et al. Hip strengthening prior to functional exercises reduces pain sooner than quadriceps strengthening in females with patellofemoral pain syndrome: a randomized clinical trial. J Orthop Sports Phys Ther. 2011;41(8):560–70.
12. Collins N, Crossley K, Beller E, et al. Foot orthoses and physiotherapy in the treatment of patellofemoral pain syndrome: randomised clinical trial. BMJ. 2008;337:a1735.
13. Barton C, Balachandar V, Lack S, et al. Patellar taping for patellofemoral pain: a systematic review and meta-analysis to evaluate clinical outcomes and biomechanical mechanisms. Br J Sports Med. 2014;48(6):417–24.
14. Mason M, Keays SL, Newcombe PA. The effect of taping, quadriceps strengthening and stretching prescribed separately or combined on patellofemoral pain. Physiother Res Int. 2011;16(2):109–19.
15. Collins NJ, Bisset LM, Crossley KM, et al. Efficacy of nonsurgical interventions for anterior knee pain: systematic review and meta-analysis of randomized trials. Sports Med. 2012;42(1):31–49.
16. Nimon G, Murray D, Sandow M, et al. Natural history of anterior knee pain: a 14- to 20-year follow-up of nonoperative management. J Pediatr Orthop. 1998;18(1):118–22.
17. Witvrouw E, Danneels L, Van Tiggelen D, et al. Open versus closed kinetic chain exercises in patellofemoral pain: a 5-year prospective randomized study. Am J Sports Med. 2004;32(5):1122–30.
18. Collins NJ, Bierma-Zeinstra SM, Crossley KM, et al. Prognostic factors for patellofemoral pain: a multicentre observational analysis. Br J Sports Med. 2013;47(4):227–33.
19. Vicenzino B, Collins N, Cleland J, et al. A clinical prediction rule for identifying patients with patellofemoral pain who are likely to benefit from foot orthoses: a preliminary determination. Br J Sports Med. 2010;44(12):862–6.
20. Barton CJ, Menz HB, Crossley KM. Clinical predictors of foot orthoses efficacy in individuals with patellofemoral pain. Med Sci Sports Exerc. 2011;43(9):1603–10.
21. Iverson CA, Sutlive TG, Crowell MS, et al. Lumbopelvic manipulation for the treatment of patients with patellofemoral pain syndrome: development of a clinical prediction rule. Including commentary by Powers CM, with authors' response. J Orthop Sports Phys Ther. 2008;38(6):297–313.
22. Lesher JD, Sutlive TG, Miller GA, et al. Development of a clinical prediction rule for classifying patients with patellofemoral pain syndrome who respond to patellar taping. J Orthop Sports Phys Ther. 2006;36(11):854–66.
23. Sutlive TG, Mitchell SD, Maxfield SN, et al. Identification of individuals with patellofemoral pain whose symptoms improved after a combined program of foot orthosis use and modified activity: a preliminary investigation. Phys Ther. 2004;84(1):49–61.
24. Piva SR, Fitzgerald GK, Wisniewski S, et al. Predictors of pain and function outcome after rehabilitation in patients with patellofemoral pain syndrome. J Rehabil Med. 2009;41(8):604–12.

25. Pattyn E, Mahieu N, Selfe J, et al. What predicts functional outcome after treatment for patellofemoral pain? Med Sci Sports Exerc. 2012;44(10):1827–33.
26. Natri A, Kannus P, Jarvinen M. Which factors predict the long-term outcome in chronic patellofemoral pain syndrome? A 7-year prospective follow-up study. Med Sci Sports Exerc. 1998;30(11):1572–7.
27. Witvrouw E, Lysens R, Bellemans J, et al. Which factors predict outcome in the treatment program of anterior knee pain? Scand J Med Sci Sports. 2002;12(1):40–6.
28. Wittstein JR, O'Brien SD, Vinson EN, et al. MRI evaluation of anterior knee pain: predicting response to nonoperative treatment. Skeletal Radiol. 2009;38(9):895–901.
29. Selfe J, Harper L, Pedersen I, et al. Cold legs: a potential indicator of negative outcome in the rehabilitation of patients with patellofemoral pain syndrome. Knee. 2003;10(2):139–43.
30. Lan TY, Lin WP, Jiang CC, et al. Immediate effect and predictors of effectiveness of taping for patellofemoral pain syndrome: a prospective cohort study. Am J Sports Med. 2010;38(8):1626–30.
31. Kannus P, Niittymaki S. Which factors predict outcome in the nonoperative treatment of patellofemoral pain syndrome? A prospective follow-up study. Med Sci Sports Exerc. 1994;26(3):289–96.
32. Barton CJ, Menz HB, Levinger P, et al. Greater peak rearfoot eversion predicts foot orthoses efficacy in individuals with patellofemoral pain syndrome. Br J Sports Med. 2011;45(9):697–701.
33. Stanton TR, Hancock MJ, Maher CG, et al. Critical appraisal of clinical prediction rules that aim to optimize treatment selection for musculoskeletal conditions. Phys Ther. 2010;90(6):843–54.
34. Kujala UM, Jaakkola LH, Koskinen SK, et al. Scoring of patellofemoral disorders. Arthroscopy. 1993;9(2):159–63.
35. Barton CJ, Webster KE, Menz HB. Evaluation of the scope and quality of systematic reviews on nonpharmacological conservative treatment for patellofemoral pain syndrome. J Orthop Sports Phys Ther. 2008;38(9):529–41.
36. Barton CJ, Munteanu SE, Menz HB, et al. The efficacy of foot orthoses in the treatment of individuals with patellofemoral pain syndrome: a systematic review. Sports Med. 2010;40(5):377–95.
37. Hume P, Hopkins W, Rome K, et al. Effectiveness of foot orthoses for treatment and prevention of lower limb injuries: a review. Sports Med. 2008;38(9):759–79.
38. van Tulder M, Furlan A, Bombardier C, et al. Updated method guidelines for systematic reviews in the cochrane collaboration back review group. Spine (Phila Pa 1976). 2003;28(12):1290–9.
39. Collins NJ, Crossley KM, Darnell R, et al. Predictors of short and long term outcome in patellofemoral pain syndrome: a prospective longitudinal study. BMC Musculoskelet Disord. 2010;11:11.
40. Mills K, Blanch P, Dev P, et al. A randomised control trial of short term efficacy of in-shoe foot orthoses compared with a wait and see policy for anterior knee pain and the role of foot mobility. Br J Sports Med. 2012;46(4):247–52.
41. Crowell MS, Wofford NH. Lumbopelvic manipulation in patients with patellofemoral pain syndrome. J Man Manip Ther. 2012; 20(3):113–20.
42. Peduzzi P, Concato J, Kemper E, et al. A simulation study of the number of events per variable in logistic regression analysis. J Clin Epidemiol. 1996;49(12):1373–9.
43. Mallen CD, Peat G, Thomas E, et al. Prognostic factors for musculoskeletal pain in primary care: a systematic review. Br J Gen Pract. 2007;57(541):655–61.
44. Noehren B, Hamill J, Davis I. Prospective evidence for a hip etiology in patellofemoral pain. Med Sci Sports Exerc. 2013; 45(6):1120–4.
45. Peters JS, Tyson NL. Proximal exercises are effective in treating patellofemoral pain syndrome: a systematic review. Int J Sports Phys Ther. 2013;8(5):689–700.
46. Crossley K, Bennell K, Green S, et al. Physical therapy for patellofemoral pain: a randomized, double-blinded, placebo-controlled trial. Am J Sports Med. 2002;30(6):857–65.