SUPPLEMENTARY MATERIAL

A Systematic Review of Reviews in Patellofemoral Pain Syndrome. Exploring the Risk Factors, Diagnostic Tests, Outcome Measurements and Exercise Treatment

Konstantinos Papadopoulos[1,2], Demetris Stasinopoulos[1] and Dimitar Ganchev[2]

[1]*School of Sciences, Department of Health Sciences, Physiotherapy programme, European University of Cyprus 6, Diogenes Str. Engomi, Nicosia, Cyprus*

[2]*Department of Kinesiotherapy, National Sports Academy (NSA) Vassil Levski, zh.k. Studentski grad, 1700, Sofia, Bulgaria*

Supplementary Material 1. RoR search engine results.

		Cinahl	SPORTDiscus	Pubmed	Pedro	Cochrane Library	Identified Summary	Selected Summary
Exercise treatment	identified	4	8	56	13	5	86	
	selected	2	5	16	6	1		30
Outcome measures	identified	6	9	71	7	2	95	
	selected	2	2	3	1	0		8
Risk Factors	identified	10	9	29	0	0	48	
	selected	2	3	7	0	0		12
Clinical tests	identified	3	3	8	1	2	17	
	selected	3	3	3	0	0		9
							246	59

Supplementary Material 2. **The type of reviews assessed their topic and which of them were included and excluded.**

	Authors	Included/Excluded with Reasons	Review Topic	Reviews were Entitled as:
1	Malanga *et al*., 2003	Included	Clinical tests	Review article
2	Nunes *et al*., 2013	Included	Clinical tests	Systematic with meta-analysis
3	Cook *et al*., 2012	Included	Clinical tests	Systematic review
4	Fredericson & Yoon, 2006	Included	Clinical tests, Risk factors	Invited review
5	Halabchi *et al*., 2013	**Excluded.** No methodology was reported	Risk factors	Review article
6	Waryasz & McDermott, 2008	Included	Risk factors	Systematic review
7	Pappas & and Wong-Tom, 2012	Included	Risk factors	Systematic with meta-analysis
8	Lankhorst *et al*., 2013	Included	Risk factors	Systematic with meta-analysis
9	Lankhorst *et al*., 2012	Included	Risk factors	Systematic with meta-analysis
10	Johnson, 1997	**Excluded.** No methodology was reported	Risk factors, general treatment	Review article
11	Thomee *et al*., 1999	**Excluded.** No methodology was reported	Risk factors, symptoms	Review article
12	Tumia & Maffulli, 2002	**Excluded.** No methodology was reported	Risk factors, Surgical treatment	Review article
13	Dixit & Difiori, 2007	**Excluded.** No methodology was reported	Risk factors. treatment	Review article
14	Heintjes *et al*., 2009	Included	Exercise treatment	Systematic with meta-analysis
15	Green, 2005	**Excluded.** No methodology was reported	Exercise treatment	Review article
16	Collins *et al*., 2012	Included	Exercise treatment	Systematic with meta-analysis

	Authors	Included/Excluded with Reasons	Review Topic	Reviews were Entitled as:
17	Bolgla & Malone, 2005	Included	Exercise treatment	Review article
18	Fagan & Delahunt, 2008	Included	Exercise treatment	Systematic review
19	Bolgla and Boling, 2011	Included	Exercise treatment	Systematic with meta-analysis
20	Harvie *et al*., 2011	Included	Exercise treatment	Systematic review
21	Powers, 1998	**Excluded.** No methodology was reported	Exercise treatment	Critical review
22	Frye *et al*., 2012	Included	Exercise treatment	Systematic review
23	Arroll *et al*., 1997	**Excluded.** Therapy type not suitable for this review	Exercise treatment combined with drugs	Critical review
24	Witvrouw *et al*., 2005	**Excluded.** No methodology was reported	Treatment	Review article
25	Crossley *et al*., 2001	**Excluded.** Combined methods with non-relative treatment components for this study	Several types of treatment	Systematic review
26	Juhn, 1999	**Excluded.** No methodology was reported	Several types of treatment	Review article
27	Baker & Juhn, 2000	**Excluded.** No methodology was reported	General treatment	Review article
28	Fulkerson, 2002	**Excluded.** No methodology was reported	Physical examination, Surgical treatment	Review article
29	Howe *et al*., 2012	Included	Outcome measures	Systematic review
30	Esculier, 2013	Included	Outcome measures	Systematic review
31	Selfe, 2004	Included	Exercise treatment, Outcome , measures Risk factors, Clinical tests	Critical Review

Supplementary Material 3. Assessment of clinical tests in PFPS.

Review	Number of Studies	Meta-Analysis	Clinical Tests in PFPS	Authors' Summary of Findings	Reviewers' Comments
Fredericson & Yoon, 2006	N/A	No	**Q-angle.** Low inter and intra-rater reliability was found in one study **Tilting.** Low-to moderate (0.3-0.5) Inter-tester and intra-tester coefficients **Mediolateral glide** Low Inter-tester and intra-tester coefficients <0.44 **Patellar compression** Moderate sensitivity and specificity<60% **Functional performance (lunges, step-down, single leg press, balance and reach** High reliability, ICC> 0.9 significant results.	The reliability of most tests is low or untreated. **Further research is necessary to establish a gold standard clinical test**	The methodology differs a lot across the studies. In addition, in some clinical tests, only one or two studies are reported. More studies are needed to strengthen the results.
Selfe, 2004	N/A	Without	**Q-angle**. The ICCs for intra-observer and inter-observer reliability of Q-angle were poor **Joint alignment** Poor Inter-tester and intra-tester coefficients. The measurements for patella alignment might be unreliable **Tilting** Poor Inter-tester and intra-tester coefficients The McConnell's classification of patellar orientation should not be used as measurement tool	No proper summary of findings due to great span of research questions	Evidence is based on individual studies. There is not enough evidence or the right methodology to conclude to any of this results
Nunes *et al*., 2013	5	Yes	**24 tests were assessed. The most useful reported were:** **Squatting** was the most sensitive test (91%), with the lowest LR- (0.2) and highest PV- (74%). **The vastus medialis coordination test** had the best specificity among all tests (93%)	Due to the multifactorial etiology of PFPS, a number of tests have been developed for its diagnosis. This review found no PFPS test with diagnostic consistency, which thus prohibits inferences about the best test to use. Future studies should	The reviewers agree that out of the 24 tests assessed in this review only the pain during squatting and the patellar tilt test have a strong tendency toward PFPS diagnosis. However,

Review	Number of Studies	Meta-Analysis	Clinical Tests in PFPS	Authors' Summary of Findings	Reviewers' Comments
			the patellar tilt had the highest LR+ (5.4) **the active instability** test had the highest PV+ (100%). Meta-analysis performed for the **patella apprehension** test. Sensitivity 15%, specificity 89%, LR+1.3, LR-1.0, PV+ 70% and PV-38%	focus on or address sample homogeneity and test standardization so that new systematic reviews with meta-analysis can more clearly determine the tests' accuracy in diagnosing PFPS.	consistency of the tests was not enough to be recommended for clinical use.
Cook *et al.*, 2012	9	No	22 tests were identified. The majority of the tests were classified as patellar mobility or palpatory measures and their specificity was more that their sensitivity. The most common tests were: **Patellar apprehension (3 times)** **Clarke's sign (4 times)** **Lateral palpation (3 times)** **None of the 22 demonstrated LR+ greater than 5.0 and LR- less than 0.20** **Active instability** test had the greatest LR+ value (LR+=249) **Pain during stair climbing** (LR+=11.6) **Clarke's sign** (LR+=7.4) **Pain during prolonged sitting** (LR+=7.4) **Patellar inferior pole tilt** (LR+=5.3) Only pain during squatting demonstrated a LR- ≤0.20 (LR-=0.20)	Values diverge so significantly across the tests because different reference standards have been used among all nine papers. Until a consistent definition of PFPS is established a reference standard will be variable leading to poor methodological study quality and widely varying diagnostic statistics. **The nebulous pathology and lack of sensitive tests suggests that PFPS may be a diagnosis of exclusion.**	The reviewers agree that the suggested tests should be used with consideration

Abbreviations: LR=Likelihood ratio, PV= predictive value.

Supplementary Material 4. Risk factors in PFPS.

Review	Number of Studies	Meta-Analysis	Risk factors in PFPS	Author's Summary of Findings	Reviewers' Comments
Fredericson & Yoon, 2006	N/A	No	**Q-angle** Contradictory results found in 5 studies **Mediolateral patellar mobility** Significant results for hypermobility of the medial glide**.** $p<0.05$ **General joint laxity** Contradictory results **Tight quadriceps** Significant results $p<0.05$ **Tight hamstrings** Contradictory results **Tight iliotibial band** Significant results $p<0.05$ **Quadriceps weakness** Contradictory results **Hip abductor weakness** Significant results $p<0.05$ **Functional performance (lunges, step-down, single leg press, balance and reach** Functional performance may be preferred over muscle deficits **General joint laxity** Unclear whether systematic hypermobility is correlated with PFPS	Multiple evaluations are recommended. The evaluation of generalized ligamentous laxity, a hypomobile or hypermobile patella, tenderness of the lateral patellar retinaculum patellar tilt or mediolateral displacement, decreased flexibility of the ITB and quadriceps, and weakness of the quadriceps, hip abductor, and external rotator are recommended to reveal factors contributing to PFPS and patellofemoral malalignment.	The methodology differs a lot across the studies. In addition, in some clinical tests, only one or two studies are reported. More studies are needed to strengthen the results.
Waryasz & McDermott 2008	24	No	**Electromyography (EMG) Measured Neuro-Motor Dysfunction** All 5 studies showed a significant neuro-motor dysfunction in PFPS	No summary of finding were presented	There is a little evidence and no comparisons between the presented studies that the reader cannot reach to a

Review	Number of Studies	Meta-Analysis	Risk factors in PFPS	Author's Summary of Findings	Reviewers' Comments
			Foot Abnormalities Not enough evidence. Additional research is needed **Functional Testing** Functional strength deficits can be a potential risk factor **Gastrocnemius Tightness** Two out of three studies reported significant results **Generalized Joint Laxity** Two out of three studies found significant results **Hamstring Strength** Data appears to be inconclusive. No p value was reported **Hamstring Tightness** Two out of four studies found significant results **Hip Musculature Weakness** Two out of three studies found significant results **Iliotibial Band Tighness (ITB)** Four studies reported significant results and one non-significant. **Q-angle** 3 studies reported significant results and four non-significant **Quadriceps Tightness** Six studies reported significant results $p<0.05$ **Quadriceps Weakness** Two studies reported non-significant results and three significant results **Patellar Compression** Data appears to be inconclusive **Patellar Mediolateral Glide** Data appears to be inconclusive **Patellar Tilting** Data appears to be inconclusive		conclusion. This is probably the reason that even the authors did not summarize their 'evidence'
Selfe, 2004			**Being a Woman** Significant difference $p<0.05$ **Military population** Significant difference $p<0.05$ **Chronic traumatic** anterior knee pain is resistant to treatment if symptoms persist beyond two years **ACL surgery** does not lead to PFPS $p<0.05$ The following factors are just reported. No further evidence was provided: **Shortened quadriceps** **Altered reflex response for Vastus Medialis Obliquus** **Decreased explosive strength** **Hypermobile patella** **Extension strength of the affected knee** **Pain on the patella apprehension test** **Patella crepitation, bilateral symptoms** **Body weight, Age** **Decreased arch index** **Decreased pronation** **Decreased knee extension peak torque**		
	N/A	No		No proper summary of findings due to great span of research questions	Evidence is based on individual studies. There is not enough evidence or the right methodology to conclude to any of this results

Review	Number of Studies	Meta-Analysis	Risk factors in PFPS	Author's Summary of Findings	Reviewers' Comments
Pappas and Wong-Tom, 2012	7	yes	**Anthropometrics** Data showed that height, weight, being military, leg discrepancy, thigh and calf circumference, tibial and foot length and foot width had no association with PFPS. Pooled data showed no association between leanness and PFPS **Physical fitness** Lower performance on vertical jump was associated with PFPS in one study and the number of push-up in another. **Muscle strength** The pooled analysis found that lower knee extension strength is a predictor of PFPS $p<0.01$, heterogeneity, $p=0.32$. One study also reports knee flexion and hip abduction as risk factor for PFPS **Joint laxity** Different methodology in the presented studies. **Muscle flexibility** One study reports that quadriceps and gastrocnemius flexibility was significant whilst hamstrings flexibility was not. **Lower leg alignment** Pooled analysis showed that Q-angle was not a predictor, $p=0.91$, heterogeneity, $p=0.22$ Contradictory results between genu varum and PFPS Foot posture did not show differences between PFPS and non-PFPS patients. **Biomechanical variables** Pooled analysis showed that peak valgus angle during landing tasks was not a predictive factor, $p=0.40$, heterogeneity, $p=0.59$ **Psychosocial parameters** Out of 11 psychosocial variables, seeking less social support and difficulty relaxing when confronted with the problem were predictors of PFPS	The main finding: despite the high incidence of PFPS among physically active populations and the abundance of factors that may predispose to this disorder, there are **few** prospective cohort studies, **especially among civilian populations.** In this small sample of studies, limited quadriceps and gastrocnemius flexibility, knee extension weakness, and faulty landing mechanics predict development of PFPS. PFPS is a multifactorial disorder. Clinicians screening populations at high risk for PFPS should evaluate strength, flexibility, and dynamic alignment.	Agree
Lankhorst *et al.*, 2013	47	Yes	Static measures **Foot and ankle characteristics** Pooling was possible in 2 out of seven studies. No association between arch height index and PFPS was found. **Leg length differences** No association was found in either two studies reported. **Q-angle in weight bearing position** Pooled data of nine studies showed that PFPS patients had a Q-angle larger than 20^0. **Malalignment** Malalignment from genu valgum was not associated with PFPS in one study **Patella** Pooling was possible for three out of 39 variables. Significant differences were found for patellar tilt angle and sulcus angle. No significance was found between congruence angle in PFPS patients and controls. **Angles** Among 18 variables the only significant were the smaller tibial tubercle rotation angle in PFPS patients compared to controls, the greater hip external rotation angle and the smaller hip internal rotation angle in PFPS compared to controls and finally the greater knee hyperextension angle **Characteristics of Vastus Medialis Obliquus (VMO) muscle** Insertion level, fabler angle and volume of VMO muscle were evaluated and were all significantly smaller in PFPS compared to controls **Characteristics of quadriceps muscles** Quadriceps atrophy was not found significant in a cross-sectional	The review provides indications that PFPS is associated with a larger Q-angle, larger sulcus angle, larger patellar tilt angle, less hip abduction strength conveyed as a percentage body weight and less knee extension strength expressed by peak torque. Other factors that were statistically significant different between PFPS patients and control subjects were based on single studies, and therefore further research is required **in high-risk groups that is, athletes and military recruits** in a prospective cohort study design.	The reviewers highlight that these studies show the great span of risk factors in PFPS. However, there is no evidence regarding the populations of the studies. Only in a few occasions the authors reported military populations. There was no evidence about athletic or normal civilians with PFPS or where the studies were conducted (research centers or clinics)

Review	Number of Studies	Meta-Analysis	Risk factors in PFPS	Author's Summary of Findings	Reviewers' Comments
			study. Kinetic measures **Foot and ankle characteristics** Less foot pronation angle during first 10% of stance during running was also find significant $p<0.05$ **Ground reaction force** Only a significant lower maximum lateral force during running in PFPS group compared to the control group was found in one study. **Peak moments** Only knee flexion-extension moment during running was significantly lower in the PFPS group compared to the control group. **Peak torques** Examined in five studies. Pooling results showed that lower knee extension at 60^0 was significant between PFPS and healthy controls. Kinematic measures **Patella** Contradictory results were found for patella malalignment **Angles** Significant larger angles were found for hip adduction peak hip internal rotation and knee flexion during functional tasks. **Velocity** The joint motions for hip adduction and hip external rotation velocity were significantly lower in PFPS patients in one study. **Excursion** A greater hip internal rotation excursion was found in PFPS patients during one-leg squat. **Peak stance-phase** Peak knee flexion in the stance phase was significantly lower in PFPS patients in two studies. Muscle function **Flexibility** Four variables were found significant in PFPS compared to healthy controls (Tightness of hamstrings, quadriceps, gastrocnemius and soleus). **Muscle strength** Pooled data showed less hip abductor strength in PFPS patients compared to controls and less hip external rotation strength. Individual studies also showed less quadriceps strength during knee extensions. **Muscle endurance** Less muscle endurance in the PFPS group was found compared to the control group expressed by eight out of ten variables. **Muscle timing** 55 studies showed no significant association between different LE muscle timings on several functional tasks. The rest studies (42) studies mostly showed EMG onset timing difference of VMO during different functional tasks. Other measures **Joint position sense** Errors between demonstrated and performed action was significant greater in PFPS in weight-bearing joint position sense at 60^0 knee flexion **Joint mobility** One study showed that PFPS patients were hypermobile compared to controls **Joint effusion** No difference were found		

Review	Number of Studies	Meta-Analysis	Risk factors in PFPS	Author's Summary of Findings	Reviewers' Comments
			Psychological factors Self-perceived health status and increased metal distress was found significant different between PFPS and healthy controls in one study. **Neurological** No difference were found **Extrinsic factors** Mileage accumulating in shoes before discarding, participating in sports before basic military, previous knee injuries, competitive sports was significant lower in PFPS group		
Lankhorst *et al.*, 2012	7	Yes	**Demographics** Pooling was possible for height, weight, body mass index, and age. No difference was found. Only one study reported that women are at higher risk. **Psychological Parameters** A significant value was found for 'looking for social support'. **Physical fitness** Participation in sports less hours per week, ability to perform more push-ups and a lower vertical jump were found as risk factors for PFPS compared to healthy controls. **Joint angles** Pooling was performed for Q-angle and no significant difference was found. No difference was also found for hip and knee angle variables **Posture** A larger medial tibial intercondylar distance was a significant risk for PFPS in 1 study. Navicular drop was significantly higher in future PFPS patients compared to controls. **Patella** No differences were found in for patella mobility **Vertical ground reaction force** Found lower in the PFPS group in one study **Plantar Pressure** Two out of 37 variables were found significant in one study. A slower maximal velocity of the change in the center of pressure in the lateromedial direction during the forefoot contact and mediolateral component of the center of the pressure was more laterally directed to the heel-metatarsal II axis in future PFPS patients than in controls. **Electromyographic onset timing of VMO and Vastus Lateralis** The onset timing of VMO before VL was significant in 80% of controls whilst this was the case in 42.3% of future PFPS patients **General joint laxity** Thumb-forearm mobility, knee extension and elbow hyper-extension were significant in PFPS compared to healthy controls. **Strength** Hip muscle strength was not associated with future occurrence of PFPS. Strength deficit of knee extension was a risk factor **Joint moments** No differences were presented **Peak torques** Pooled data for concentric peak torque of the knee flexors and extensors during isokinetic testing relative to body weight measured at 60^0/s and 240^0/s was significantly associated with future PFPS. Lower concentric peak torques for the knee extensors, measured by at 60^0/s and 240^0/s were statistically risk factors for future PFPS. The concentric flexor-extensor peak torque ratios measured at 60°/s and 240°/s were significantly higher in those with future PFPS compared to those in the control group	The results of the study indicate that less knee extension strength is significantly associated with a higher risk for future PFPS. It is noteworthy that most evaluated risk factors in the 7 studies were biomechanical and neuromuscular risk factors and not structural (static) risk factors. Structural abnormalities and lower extremity malalignment are often examined as associative factors for PFPS in case-control studies.	The reviewers observed that although this systematic review is a high standard because it includes RCTs only, the results are based on less than 10 PFPS individuals for each variable. Therefore the interpretation of the data should be done with consideration. Unfortunately there are still only a few RCTs and generalization of the evidence is difficult. In addition the authors did not report enough data about the patient characteristic of the RCTs.

Abbreviations: ACL= Anterior cruciate ligament.

Supplementary Material 5. Exercise treatment in PFPS.

Review	Number of Studies	Meta-Analysis	Exercise Treatment in PFPS	Authors' Summary of Findings	Reviewers' Comments
Fagan and Delahunt, 2008	11	No	**Efficacy of hip joint musculature strengthening in subjects with PFPS** No evidence to suggest that hip joint strengthening can improve symptoms in subjects with PFPS **Efficacy of physiotherapeutic interventions aimed at addressing quadriceps muscle imbalances in subjects with PFPS** Strong evidence to suggest that physiotherapeutic intervention is efficacious in addressing quadriceps muscle imbalances in subjects with PFPS **Efficacy for open versus closed kinetic chain exercises in subjects with PFPS** Strong evidence to suggest that both open and closed kinetic chain exercises are beneficial in reducing symptoms associated with PFPS	There are currently no RCTs to support the efficacy of hip joint musculature strengthening in subjects with PFPS. However, a number of intervention studies do support its use in clinical practice. Physiotherapy intervention programs appear to be an efficacious form of intervention for addressing quadriceps muscle imbalances. Both OKC and CKC exercises appear to be appropriate forms of treatment for subjects with PFPS.	The reviewers agree that research should focus on long term-follow-ups. If 91% of respondents continue to have knee pain after they get treated and 1 out of 4 patients continue to have knee pain for the next 20 years, then what is the point of talking about the efficacy of exercise treatment?
Bolgla and Malone, 2005	N/A	No	<u>**Open kinetic exercise (OKC)**</u> **Hip muscle strengthening** Studies relating to the role of the musculature proximal to the knee are limited. There is no specific evidence to support the theory that hip muscle strengthening could help patients with PFPS **Isometric quadriceps exercise** Patients with PFPS can benefit from isometric quadriceps-strengthening and SLR exercises. Exercises should be performed in a pain free range of motion **Isokinetic exercises** Results have shown that patients with PFPS can benefit from isokinetic exercises <u>**Closed kinetic chain (CKC) exercises**</u> Results from several studies have shown that closed chain exercises are also beneficial. However, all exercises should be performed in a pain- free manner.	Although might have a bias toward either OKC or CKC exercise, either type of exercise can benefit PFPS population.	The reviewers took into consideration that the authors included studies with a minimum of 4-week (12 visits according to their report) intervention. They also used this criterion as an evaluation of evidence clearly stating in the review that this method would be better than a meta-analysis. The reviewers consider whether clinicians in national healthcare services see their patients 12 times in 4 weeks.
Selfe, 2004	N/A	No	Initial strengthening should be performed at 40° of knee flexion. **Open kinetic chain exercises** should be avoided in the first 30° of knee joint flexion. **Closed kinetic chain** exercises may be more effective than joint isolation exercise in restoring function in patients with PFPS. **No differences** were found between OKC and CKC exercises. **Function activity** is composed of both OKC and CKC components and each is important in the rehabilitation.	Both **isometric** exercises and **eccentric** exercises improved PFPS patients **significantly**. Both exercises should be performed pain free. Clinicians should consider **less intensity** and **longer time** periods in the management of PFPS. **Home-based exercises** are a cheaper alternative and appear to be slightly more effective than formal physiotherapy and should be tried for six weeks before instituting formal physiotherapy	There is no much evidence to support the conclusions of this review. Most of the suggestions are based on individual studies
Frye *et al*., 2012	10	No	**Single exercises** had significant improvement in pain and so did exercise prescriptions that included flexibility, strength and muscle balance (quadriceps, adductors and gluteals) Only 1 study showed that **exercise did not improve pain;** however results suggested that adding transverse abdominis, hip abductor and lateral rotator muscles may improve the pain outcomes in PFPS patients Several studies reported that patients with PFPS	Exercise interventions including quadriceps, hip abductor, gluteal muscle strengthening, leg presses, closed chain exercises, lower extremity strengthening and ITB stretching are effective for PFPS patients and can immediately decrease pain and increase function. However, these data suggest that	The reviewers feel that they need to emphasize a little bit more than the authors the fact that half of the studies (4) **did not include control groups.** Therefore, the conclusions should be treated with reservation

Review	Number of Studies	Meta-Analysis	Exercise Treatment in PFPS	Authors' Summary of Findings	Reviewers' Comments
			will benefit from doing **exercise** rather than **nothing** **Patient education-including activity recommendations, sham treatments, low intensity exercises and anti-inflammatory drugs** have a role in improving patient outcomes, however; when the patients are treated with various interventions it is difficult to isolate the source of improving. In patients who had benefited from exercise interventions or home exercise programs, patient outcomes clearly **diminished once the rigorous guidance stopped.**	improvements may not be maintained after a short-term follow-up	
Collins *et al*., 2012	13 studies on exercise, 27 in total	Yes	**Evidence from RCTs support the use of exercise for AKP.** Three studies showed significant effect favouring exercise over a no-treatment control Both **closed and open kinetic chain** exercises have shown large to very large effects favouring both types of exercise. **Leg press with hip abduction** showed significant moderate effect over controls. **Contrasting results** were reported in the comparison of short-time **open and closed chain exercises.** One study showed that closed chain exercises had a significant moderate effect over open chain exercises whilst another showed no difference. A 5-year follow-up study showed a significant small effect in favour of open chain exercises. All RCT studies reported that **the addition of hip components**, supervision or other adjunct interventions to quadriceps-based programmes **did not change** AKP outcomes. **No** difference was found between **supervised & unsupervised home** exercises.	Until further high-quality RCTs are conducted addressing issues of sample size, long-term follow up and adherence to the CONSORT statement, sports medicine practitioners should prescribe local, proximal and distal components of multimodal physiotherapy for appropriate AKP patients	Agree
Bolgla and Boling, 2011	22	No	**Hip strengthening** Hip strengthening exercises can benefit individuals with PFPS. Moderate evidence has supports the use of hip abductor and external rotators strengthening. **Clinicians should consider an exercise dosage focusing on endurance and high repetitions** **Quadriceps strengthening** Clinicians may prefer weight bearing exercises that stimulate functional activities. However, the use of non-weight exercises may be equally beneficial	Quadriceps exercise continues to represent an important treatment strategy. This review also supported the addition hip strengthening exercises. However there is a need to isolate the effect of hip strengthening on PFPS.	Agree
Harvie *et al*., 2011	10	No	**Type of exercise** Both open and closed chain kinetic exercises are suggested for PFPS **Program duration** An intervention of 6-weeks could be considered for programs targeting PFPS **Frequency and intensity** The majority of studies prescribed 5 or more days of exercises per week. However it is also supported that frequency of training should be chosen with respect to the type of exercise and perceived goals of training and progression should be considered where strength is a target of intervention. **Strength**	These myriad of exercise options provide clinicians with the flexibility to tailor their exercise programs to suit individual needs. Each program should be used independently or in combination with other treatments. Compliance with exercise is the main problem and future studies should focus on this component of treatment.	Agree

Review	Number of Studies	Meta-Analysis	Exercise Treatment in PFPS	Authors' Summary of Findings	Reviewers' Comments
			The high reporting of exercises that strengthened both hip and knee muscle groups among programs which demonstrated positive outcomes supports their inclusion in exercise programs and reflects the hip and knee strength deficits that shown to exist in patients with PFPS **Flexibility** The frequent inclusion of stretching (hamstrings, quadriceps, gastrocnemius Iliotibial band and anterior hip stretches) in studies reporting positive outcomes support the use of stretching as an inclusion in exercise protocols **Selective muscle/recruitment/muscle timing** The review reports that clinicians should not overly focus on the VL/VMO timing difference **Sets and repetitions** A minimum of 20-40 total repetitions should be considered when prescribed exercises for PFPS		
Heintjes *et al*., 2009	12	Yes	**Exercise versus no exercise** There is limited evidence to support the hypothesis that exercise therapy reduces anterior knee pain in patients with PFPS. There is conflicting evidence that exercise can reduce both pain and function. **Open kinetic chain versus closed kinetic chain** The results of both high and low quality RCTs are consistent for both pain and function. Closed chain exercises provide equal results to open kinetic chain exercises for either pain reduction or function improvement.	Based on limited evidence for effectiveness, physicians may consider exercise therapy for the treatment of PFPS. Future research should focus on a larger number of participants Power calculation are needed before conducting each study	

Supplementary Material 6. Outcome measures in PFPS.

Review	Number of Studies	Meta-Analysis	Outcome Measures in PFPS	Author's Summary of Findings	Reviewers' Comments
Selfe, 2004	N/A	No	The **FIQ** was ranked as the easiest questionnaire to complete. The **Flandry** questionnaire was ranked as the best for accurately depicting symptoms but it was also very confusing The **MFIQ** was recommended to be used routinely in the UK with a change in score of 10 point or more probably being clinically significant	No additional summary	The individual primary study from the same author of this review is not enough evidence to propose the MFIQ for clinical use.
Howe *et al*., 2012	12 on PFPS 47 in total	No	**AKPS** contains most of the functional limitations identified except kneeling. It shows good content validity and is responsive to change. It includes questionnaires not clear to patients (atrophy of thighs) **Goniometer** Parallelogram and universal goniometer were reported with good intra-tester reliability. A significant difference was found between goniometer and radiographic measures of knee extension in one study. **LEFS** It shows excellent reliability (r=0.94) and is more responsive than AKPS in detecting change in AKP. It is not specific for any condition especially ligamentous lesions.	Only the AKPS was developed for PFPS, whilst LEFS was developed for general conditions. Many other tests such as the PSS, PSFS, VAS, Lysholm, PFPS impairment scale, FIQ and ADLS scale were assessed in PFPS populations but with several results.	Agree

Review	Number of Studies	Meta-Analysis	Outcome Measures in PFPS	Author's Summary of Findings	Reviewers' Comments
Esculier *et al*., 2013	24	No	<u>**Validity**</u> **Content validity** Content and face validity for ADLS and Lysholm scale were found to be adequate. Only 4.4% of the AKPS items were left unanswered. Regarding FIQ, 20-30% of the 56 patients marked the questions about walking and running as unknown. However, in another study FIQ was chosen as the easiest questionnaire to complete but the AKPS was better to describe symptoms. **Construct validity** Moderate to high correlations 0.50-0.90 were reported in a number of studies which compared ADLS-Lysholm scale, IKDC-Lysholm scale and AKPS-FIQ. Moderate to strong correlation were also found previous questionnaires and other scales such as the WOMAC, physical component of SF-36 and the VAS. **Known-group validity** ADLS, AKPS and Lysholm scale were found to be able to differentiate PFPS from other knee conditions. ADLS was found to have the best known-group validity whilst, the FIQ and IKDC have not been evaluated yet. **Factorial validity** Only IKDC and ADLS had this structural aspect of validity investigated in PFPS patients. Two studies found that the IKDC had a single dominant component (symptoms function and sport activity) whilst a third reported two; symptoms and knee articulation and activity limitations. Therefore, all three concluded that the IKDC is a one- or two-dimension scale. These dominant components are The ADLS was found to have two factors; named Symptoms and functional limitations. **Language and cultural adaption** The AKPS, ADLS and IKDC have been translated and culturally adapted in many languages. **Administration burden/time to administer** The time to administer has only been established in the Thai version of the IKDC (less than 10 minutes). All versions of the translated scales were found to have adequate construct validity. <u>**Reliability**</u> **Test-retest reliability** Except for FIQ all the rest reviewed scales (AKPS, ADLS, IKDC and Lysholm scale) reported excellent test-retest reliability (0.81-0.99). **Absolute reliability** Low for ADLS, IKDC, AKPS and higher for the FIQ and Lysholm scale **Internal consistency** Cronbach α was reported from 0.81 to 0.93 for ADLS, AKPS, FIQ and IKDC. Lower for Lysholm scale (0.66) <u>**Responsiveness**</u> **Effect size and standardized response mean** ADLS, AKPS, IKDC and Lysholm scale were highly responsive in patients with PFPS with ES or SRM≥0.90. FIQ had moderate responsiveness ES=0.59. When compared the AKPS was more responsive than the FIQ following conservative treatment and ADLS was more responsive than Lysholm scale following non-operative treatment. **Clinically important difference** Smallest change that represents an important difference for patient (CID) was established for all scales except Lysholm. CID was lower for FIQ that for AKPS in one study (FIQ 6.3%; AKPS 8%in one study and 19 in another). CID of 7% was found for ADLS and 11.5% for IKDC **Longitudinal validity** Changes in a global rating of change measure correlate moderately to strongly (r>0.50) with change in ADLS, moderate with changes (0.50<r<0.70) in Lysholm and FIQ, low to moderate (0.30<r<0.70) with changes in AKPS	Among the five commonly used knee-specific scales the use of the ADLS is recommended for individuals with PFPS. The AKPS and IKDC would be appropriate for PFPS but properties still need to be defined in larger samples. The FIQ and Lysholm scale are not recommended for individuals with PFPS.	The reviewers agree with the authors' conclusions, however they think that an important limitation is the criterion of excluding studies with less than five publications on PFPS. Therefore 10 scales including the LEFS and the WOMAC, PFPS severity scale were not mentioned in this review. Future research should focus on these scales as well.

Abbreviations: FIQ= Function index questionnaire, MFIQ= modified function index questionnaire, *AKPS= Anterior Knee Pain Scale, WOMAC= Western Ontario and McMaster Universities Arthritis Index, CID= Clinical Importance Different, IKDC= International Knee Documentation Committee, ES= Effect Size; SRM: Standardized Response Mean, ADLS= Activities of Daily Living Scale, LEFS= Lower Extremity Functional Scale, AKP= Anterior Knee Pain, VAS= Visual Analogue Scale, PSFS= Patient Specific Functional Scale, PSS=Patellofemoral Severity Scale.*

Supplementary Material 7. Characteristics of the primary studies included in the systematic reviews.

Systematic Review	Original Paper	Athletes/ Non-Athletes	No of Participants	Gender	Country	Setting	Study Design	Dynamometers
Nunes *et al*., 2013	Haim *et al*., 2006	Military	61 PFPS 25 controls	86 males	Israel	Military base	Controlled clinical trial	No
	Naslund *et al*., 2006	Unclear	29 PFPS 17 controls	15 women with PFPS 14 men with PFPS 12 female controls 5 male controls	Sweden	University hospital	Controlled clinical trial	No
	Nijs *et al*., 2006	Outpatients	20 PFPS 19 controls	9 women with PFPS 11 men with PFPS 5 female controls 14 male controls	Belgium	University	Controlled clinical trial	No
	Cook *et al*., 2010	Athletic participants	52 PFPS 24 controls	17 women with PFPS 25 males with PFPS 8 male controls 13 female controls	USA	Sports medicine practice	Prospective, consecutive-subjects design	No
	Sweitzer *et al*., 2010	Unclear	59 PFPS 23 controls	Unclear	USA	Orthopaedic Clinic	Inter-rater reliability	No
Cook *et al*., 2012	Doberstein *et al*., 2008	Unclear	106 healthy	37 women 69 men	USA	University	Validation study	No
	Elton *et al*., 1985		20 PFPS	Unclear	USA	University	Pilot study	Cybex isokinetic (non-portable)
	Niskanen *et al*., 2001	Unclear	85 PFPS	44 females 41 men	Finland	Hospital	Prospective study	No
	Pihlajamak *et al*., 2010	Military	56 PFPS	56 men	Finland	Hospital	Prospective	No
Duplicates	**Sweitzer *et al*., 2010** **Cook *et al*., 2010** **Haim *et al*., 2006** **Naslund *et al*., 2006** **Nijs *et al*., 2006**							
Waryasz & McDermott, 2008	Witvrouw *et al*., 2000	Young athletes	282 subjects 24 revealed PFPS after 2 years	Unclear	Belgium	University	Prospective study	Cybex 2 (non-portable)
	Milgrom *et al*., 1991	Military	390 non-PFPS patients	All men	Israel	Hospital	Prospective cohort	Hand-held dynamometer
	Cowan *et al*., 2002a	Unclear	37 PFPS 37 controls	23 women with PFPS 14 men with PFPS 23 female controls 14 female controls	Australia	University	Cross-sectional	No
	Cowan *et al*., 2001	Unclear	33 PFPS 33 Controls	11 men with PFPS 22 women with PFPS 13 male controls 20 female controls	Australia	University	Cross-sectional	No
	Crossley *et al*., 2004	Unclear	48 PFPS 18 controls	31 women with PFPS 17 men with PFPS	Australia	University	Randomised double-blinded placebo-	No

Systematic Review	Original Paper	Athletes/ Non-Athletes	No of Participants	Gender	Country	Setting	Study Design	Dynamometers
				9 female controls 9 male controls			controlled trial	
	Thomee *et al*., 1996	Unclear	11 PFPS 9 controls	9 women with PFPS 11 unknown	Sweden	University	Case-control study	Kin-com dynamometer (non-portable)
	Thomee *et al*., 1995a	Athletic	40 PFPS 20 controls	All women	Sweden	University	Case-control study	No
	Thomee *et al*., 1995b	Athletic	40 PFPS 20 controls	All women	Sweden	University	Case-control study	KinCom dynamometer (non-portable)
	Loudon *et al*., 2002	Unclear	29 PFPS 11 controls	19 women with PFPS 10 men with PFPS Controls unclear	USA	Clinic	Test-retest reliability	No
	Piva *et al*., 2005	Average population	30 PFPS 30 controls	17 women with PFPS 13 men with PFPS 17 female controls 13 male controls	USA	University laboratory	Case-control study	Hand-held dynamometer
	Fairbank *et al*., 1984	Outpatients	52 with knee pain 446 adolescents (pupils)	Unclear	UK	Hospital and school	Case-control	No
	Cichanowski *et al*., 2007	Athletic patients	13 PFPS 13 controls	All women	USA	Unclear	Case-control	Hand-held dynamometer
	Ireland *et al*., 2003	Athletic patients	15 PFPS 15 controls	All women	USA	Clinic	Cross-sectional	Hand-held dynamometer
	Winslow *et al*., 1995	Dancers	12 PFPS 12 controls	All women	UK	Unclear	Case-control	No
	Caylor *et al*., 1993	Unclear	50 PFPS 26 controls	32 women with PFPS 18 men with PFPS	USA	University	Reliability study	No
	Messier *et al*., 1991	Runners	16 PFPS 20 control	Unclear	USA	Lab of biomechanics	Case-control	Isokinetic Dynamometer (non-portable)
	Callaghan & Oldham, 2004	Outpatients	57 with PFPS 10 controls	35 women with PFPS 22 men with PFPS 6 female controls 4 male controls	UK	Hospital	Cross-sectional	Biodex dynamometer (non-portable)
	Kibler, 1987	Athletes	76 PFPS	Unclear	USA	Unclear	Clinical trial-not controlled	Cybex (non-portable)
	Puniello, 1993	Active patients	17 PFPS	16 women 1 man	USA	Private practice setting	Clinical trial-not controlled	No
	Bennett & Stauber, 1986	Unclear	130 patients with various knee problems	Unclear	USA	University laboratory	Cross-sectional	Kin-com dynamometer (non-portable)
Duplicates	**Smith *et al*., 1991** **Haim *et al*., 2006** **Aglietti 1983** **Niskanen *et al*., 2001**							

Systematic Review	Original Paper	Athletes/ Non-Athletes	No of Participants	Gender	Country	Setting	Study Design	Dynamometers
Pappas & and Wong-Tom, 2012	Boling *et al*., 2009	Naval populations	1597 asymptomatic 40 had PFPS after 2.5 years	632 women 965 males 16 males 24 women reported PFPS after 2.5 years	USA	Army center for health	Prospective cohort	Hand-held dynamometer
	Thijs *et al*., 2007	Military	84 asymptomatic 36 Reported PFPS after six-weeks training	65 males 19 women 25 males 11 females Reported PFPS after six-weeks training	Belgium	University	Prospective cohort	No
	Thijs *et al*., 2008	Runners	102 asymptomatic 17 reported PFPS after 10 weeks	89 women 13 men 16 females 1 male reported PFPS after 10 weeks	Belgium	University	Prospective cohort	No
	Van Tiggelen *et al*., 2009	Military	79 healthy subjects 25 reported PFPS after a six-week;s training	Unclear	Belgium	Unclear	Prospective cohort	No
Duplicates	**Witvrouw *et al*., 2000** **Milgrom *et al*., 1991**							
Lankhorst, *et al*., 2013	Aglietti 1983	Unclear	53 knees with subluxation	Unclear	Italy	Unclear	Case-control	No
	Alberti *et al*., 2010	Unclear	30 PFPS 44 controls	26 women with PFPS 4 men with PFPS 26 female controls 4 male controls	Brazil	University	Case-control	No
	Al-Rawi 1997	General population	115 PFPS 110 controls	89 women with PFPS 26 men with PFPS 89 female controls 26 male controls	Iraq	Unclear	Case-control	No
	Anderson 2003	Athletic	20 PFPS 20 controls	All women	UK	Unclear	Case-control	Cybex dynamometer (non-portable)
	Baker *et al*., 2002	Unclear	20 PFPS 20 controls	15 women with PFPS 5 men with PFPS 15 female controls 5 male controls	Australia	University	Cross-sectional	No
	Barton *et al*., 2010	Unclear	20 PFPS 20 controls	15 women with PFPS 5 men with PFPS 15 female controls 5 male controls	Australia	University	Case-control and reliability study	No
	Besier *et al*., 2008	Unclear	26 PFPS 16 controls	16 women with PFPS 11 men with PFPS 8 female controls	USA	University	Case-control	No

Systematic Review	Original Paper	Athletes/ Non-Athletes	No of Participants	Gender	Country	Setting	Study Design	Dynamometers
				8 male controls				
	Crossley *et al*., 2003	Unclear	48 PFPS 18 controls	31 women with PFPS 17 men with PFPS 9 female controls 9 male controls	Australia	University	Cross-sectional	No
	Dierks *et al*., 2008	Runners	20 PFPS 20 controls	15 women with PFPS 5 men with PFPS 15 female controls 5 male controls	USA	University	Cross-sectional	Hand-held dynamometer
	Dorotka *et al*., 2002	Military	133 PFPS 115 controls	All men	Germany	Military center	Case-control	No
	Draper 2006	Active patients	34 PFPS 16 controls	22 women with PFPS 12 men with PFPS 8 female controls 8 male controls	USA	University	Case-control	No
	Draper 2009	Active patients	23 PFPS 13 controls	All women	USA	University	Case-control	No
	Duffey *et al*., 2000	Runners	99 PFPS 70 controls	31 women with PFPS 68 men with PFPS 17 female controls 53 male controls	USA	University	Case-control	Cybex 2 dynamometer (non-portable)
	Eckhoff *et al*., 1994	Unclear	20 PFPS 10 controls	Unclear	USA	University	Case-control	No
	Emami *et al*., 2007	Outpatients	100 PFPS 100 controls	56 women with PFPS 44 men with PFPS 50 female controls 50 male controls	Iran	Hospital	Case -control	No
	Jan *et al*., 2009	Unclear	54 PFPS 54 controls	41 women with PFPS 13 men with PFPS 41 female controls 13 male controls	Taiwan	University	Case-control	No
	Jensen *et al*., 2008	Unclear	91 PFPS 23 controls	Unclear	Norway	University	Case-control	No
	Joensen *et al*., 2001	Athletes	24 PFPS 17 controls	Unclear	Denmark	Unclear	Case-control	No
	Keser *et al*., 2008	Unclear	109 knees with PFPS 74 knees without	Unclear	Turkey	University	Case-control	No
	Laprade *et al*., 2003	Military	33 PFPS 33 controls	Unclear	Canada	University	Case-control	No
	Livingston *et al*., 2003	Mostly athletic	25 PFPS 50 controls	14 women with PFPS 11 men with PFPS 24 female controls 26 male controls	Canada	University	Single-session observational study	No

Systematic Review	Original Paper	Athletes/ Non-Athletes	No of Participants	Gender	Country	Setting	Study Design	Dynamometers
	MacIntyre *et al*., 2006	Unclear	40 PFPS 20 controls	Unclear	Canada	University	cross-sectional case-control	No
	Magalhaes *et al*., 2010	Sedentary	50 PFPS 50 controls	All women	Brazil	Unclear	Case-control	Hand-held dynamometer
	McClinton *et al*., 2007	Unclear	20 PFPS 20 controls	9 women with PFPS 11 men with PFPS 10 female controls 10 male controls	USA	University	Case-control	No
	Morrish 1997	Unclear	49 PFPS 20 controls	Unclear	UK	University	Case-control	No
	Muneta *et al*., 1994	Unclear	60 PFPS 19 controls	All women	Japan	University	Case-control	No
	Näslund *et al*., 2007	Unclear	22 PFPS 33 controls	Unclear	Sweden	University	Case-control	No
	Ota *et al*., 2008	Unclear	22 PFPS 22 controls	All women	Japan	Unclear	Case-control	Hand-held dynamometer
	Owings, 2002	Unclear	20 PFPS 14 controls	12 women with PFPS 8 men with PFPS 4 female controls 10 male controls	USA	University	Controlled laboratory design	Kin-com dynamometer
	Patil *et al*., 2011	Unclear	20 PFPS 17 controls	Unclear	UK	Unclear	Case control	No
	Patil *et al*., 2010	Athletic	20 patients 17 controls	12 women with PFPS 8 men with PFPS 10 female controls 7 male controls	UK	Unclear	Case-control	No
	Powers *et al*., 2000	Unclear	23 PFPS 12 controls	All women	USA	University	Case control	Lido dynamometer (non-portable)
	Powers *et al*., 1996	Unclear	26 PFPS 19 controls	All women	USA	University	Case control	Lido dynamometer (non-portable)
	Salsich *et al*., 2007	Unclear	21 PFPS 21 controls	16 women with PFPS 5 male with PFPS 14 female controls 7 male controls	USA	unclear	Observational, cohort study	No
	Souza 2009	Active	21 PFPS 20 controls	All women	USA	University	Controlled laboratory study using a cross-sectional design.	Primus dynamometer (non-portable)
	Stefanyshyn *et al*., 2006	Runners	20 PFPS 20 controls	Unclear	Canada	University	Case-control	No
	Tuncyurek *et al*., 2010	Outpatients	23 PFPS 9 controls	Unclear	Turkey	Hospital	Case-control	No
	Werner *et al*., 1995	Athletic	27 PFPS 27 controls	14 women with PFPS 13 males with PFPS	Sweden	University	Case-control	Kin-com Dynamometer (non-portable)

Systematic Review	Original Paper	Athletes/ Non-Athletes	No of Participants	Gender	Country	Setting	Study Design	Dynamometers
				14 female controls 13 male controls				
	Willson *et al*., 2008	Unclear	20 PFPS 20 Controls	All women	USA	University	Case-control	No
Duplicates	**Boling *et al*., 2009** **Callaghan and Oldham 2004** **Caylor *et al*., 1993** **Cowan *et al*., 2001** **Cowan *et al*., 2002b** **Haim 2006** **Piva *et al*., 2005** **Thomee *et al*., 1995b**							
Lankhorst *et al*., 2012	Van Tiggelen *et al*., 2004	Military	96 without knee pain 31 revealed PFPS after a six week's training. 65 controls	Unclear	Belgium	Unclear	Prospective study	Isokinetic dynamometer (non-portable)
	Duvigneaud *et al*., 2008	Military	62 without knee pain. 26 revealed PFPS after a six-week's training	All women	Belgium	Unclear	Prospective study	Isokinetic dynamometer (non-portable)
Duplicates	**Milgrom *et al*., 1991** **Thijs *et al*., 2007** **Van Tiggelen *et al*., 2009** **Boling *et al*., 2009** **Witvrouw *et al*., 2000**							
Heintjes *et al*., 2009	Clark *et al*., 2000	General population	81 PFPS	45 men 36 women	UK	Research center	Randomised controlled trial	Tornvall chair (non-portable)
	Timm *et al*., 1998	Unclear	100 PFPS	50 men 50 females	USA	Hospital	Randomised controlled trial	No
	McMullen *et al*., 1990	Unclear	29 PFPS	16 men 13 females	USA	University	Cohort clinical trial	Isokinetic dynamometer
	Wijnen *et al*., 1996	Unclear	18 PFPS	5 men 13 women	Netherlands	Outpatient clinic	Randomised controlled trial	No
	Stiene *et al*., 1996	Unclear	33 PFPS	13 men 20 women	USA	Sports medicine center	Cohort clinical trial	Isokinetic dynamometer (non-portable)
	Gaffney *et al*., 1992	Unclear	72 PFPS	47 men 25 women	UK	Unclear	Randomised controlled trial	No
	Colon *et al*., 1998	Athletes	29 PFPS	19 men 10 women	UK	unclear	Randomised controlled trial	Unclear
	Harrison *et al*., 1999	Unclear	113 PFPS	Unclear	Canada	University	Randomised controlled trial	No
	Dursun *et al*., 2001	Unclear	60 PFPS	48 women 12 men	Turkey	University	Randomised controlled trial	No
	Thomee *et al*., 1997	Athletic patients	40 PFPS	40 women	Sweden	Unclear	Randomised controlled trial	Kin-Com dynamometer (none-portable)

Systematic Review	Original Paper	Athletes/ Non-Athletes	No of Participants	Gender	Country	Setting	Study Design	Dynamometers
	Gobelet *et al*., 2001	Unclear	120 patients with patellar chondromalacia	Unclear	Switzerland	Hospital	Randomised controlled trial	Cybex 2 (non-portable)
Duplicate	**Witvrouw *et al*., 2000**							
Collins *et al*., 2012	Witvrouw *et al*., 2004	Unclear	60 PFPS	40 females 20 males	Belgium	Hospital	Prospective randomized clinical trial, no control	Cybex isokinetic (non-portable)
	Herrington and AL-Sherhi, 2007	Unclear	45 PFPS	45 males	UK	University	Randomised control trial	Isokinetic dynamometer
	Nakagawa *et al*., 2008	Unclear	14 PFPS	10 women 4 men	Brazil	Clinical setting with home program	Randomized control trial	No
	Song *et al*., 2009	Unclear	89 PFPS	20 males 69 females	Taiwan	Kinesiology lab	Randomised control trial	no
	Taylor & Brantingham, 2003							
	Van Linschoten *et al*., 2009	Unclear	131 PFPS	47 men 84 women	Netherlands	Sport physician practice	Open-label randomized control trial	no
	Wiener-Ogilvie and Jones, 2004	Unclear	21 PFPS	unclear	UK	Unclear	Randomized trial	unclear
	Bakhtiary & Fatemi, 2008	Students	32 PFPS	32 women	Iran	University	Quasi-experimental	Isokinetic dynamometer (non-portable)
	Witvrouw *et al*., 2003	Unclear	60 PFPS	40 females 20 males	Belgium	Hospital	Prospective randomized clinical trial, no control	Cybex isokinetic (non-portable)
Duplicates	**Clark *et al*., 2000** **Harrison *et al*., 1999** **Witvrouw *et al*., 2000**							
Fagan & Delahunt, 2008	Cowan *et al*., 2006	Athletic participant	10 PFPS 12 controls	Unclear	Australia	University	Randomised controlled trial	No
	Keet *et al*., 2007	Athletic participants	15 PFPS 20 controls	11 women with PFPS 4 men with PFPS 13 healthy women 7 healthy men	South Africa	Research center	Placebo controlled clinical trial with randomized interventions	Isokinetic dynamometer (non-portable)
	Masca, *et al*., 2003	Civilians	2 PFPS	2 women	USA	Clinic	2 case reports	Hand-held dynamometer
	Tyler *et al*., 2006	Athletic participants	35 PFPS	29 women 6 men	USA	Clinic/home	Cohort study	Hand-held dynamometer
	Boling *et al*., 2006	General population	14 PFPS 14 controls	5 males with PFPS 9 Women with PFPS 5 male controls 9 women controls	USA	Musculoskeletal research lab	Pre/post intervention study	No
	Cowan *et al*., 2002c	Unclear	10 PFPS 12 controls	3 males with PFPS 7 females with PFPS 4 male controls 8 female controls	Australia	University	Randomised controlled trial	No

Systematic Review	Original Paper	Athletes/ Non-Athletes	No of Participants	Gender	Country	Setting	Study Design	Dynamometers
	Cowan *et al*., 2002b	Unclear	65 PFPS	42 women 23 males	Australia	Research institute	Randomized controlled trial	no
Duplicates	**Cowan *et al*., 2001** **Witvrouw *et al*., 2000** **Witvrouw *et al*., 2004** **Herrington and AL-Sherhi, 2007**							
Bolgla and Boling, 2011	Fakuda *et al*., 2010	Sedentary women	70 PFPS	70 women	Brazil	University settings Exercises were performed at home	Randomised controlled trial	No
	Bily *et al*., 2008	Unclear	38 PFPS	14 men 24 women	Austria	University	Randomized clinical trial	Chair with full bridge circuit and amplifier
	Hazneci *et al*., 2005	Military population	24 PFPS 24 Controls	24 male patients 24 male controls	Turkey	Research center	Quasi-experimental	Isokinetic dynamometer (non-portable)
	Syme *et al*., 2009	NHS patients	69 PFPS	41 women 28 men	UK	NHS Hospital	Randomized control trial	No
	Crossley *et al*., 2002	Unclear	71 PFPS	46 women 25 men	Australia	Unclear	Randomized control trial	No
	Whittingham *et al*., 2004	Military populations	30 PFPS	24 men 6 women	UK	Military	Randomized control trial	No
	Lun *et al*., 2005	Active runners	129 PFPS	57 men 79 women	South Africa	University	Quasi-experimental	No
	Denton *et al*., 2005	Unclear	34 PFPS	34 women	USA	Sports care and physical therapy clinic	Randomized clinical trial	No
	Collins *et al*., 2009	Active runners	179 PFPS	100 women 79 men	Australia	University	Randomized control trial	No
	Johnston and Gross, 2004	Unclear	16 PFPS	13 women 3 men	USA	University	Observational study	No
Duplicates	**Boling *et al*., 2006** **Clark *et al*., 2000** **Witvrouw *et al*., 2000** **Witvrouw *et al*., 2004** **Dursun *et al*., 2001** **Herrington & Al-Sherhi, 2007** **Song *et al*., 2009** **Loudon *et al*., 2004** **Mascal *et al*., 2003** **Nakagawa *et al*., 2008** **Bakhtiary & Fatemi, 2008**							
Harvie *et al*., 2011	Kettunen *et al*., 2007	No specific characteristics. PFPS patients who visited the Orthopaedic Hospital,	56 patients with PFPS separated in two groups	21 men 36 women	Finland	Hospital settings Exercises were performed at home	Randomized controlled trial	No
Duplicates	**Clark *et al*., 2000** **Crossley *et al*., 2002** **Nakagawa *et al*., 2008** **Bakhtiary and Fatemi, 2008**							

Systematic Review	Original Paper	Athletes/ Non-Athletes	No of Participants	Gender	Country	Setting	Study Design	Dynamometers
	Witvrouw *et al*., 2000 **Herrington and Al-Sherhi, 2007** **Syme *et al*., 2009** **Van Linschoten *et al*., 2009** **Song *et al*., 2009**							
Frye *et al*., 2012	Ferber *et al*., 2011	active recreational athletes running at least 30 minutes per day	15 PFPS 10 controls	PFPS 5 men 10 women Controls 4 men 6 women	Canada	Clinic	Cohort study	Portable, force-dynamometer
	Alaca *et al*., 2002	Active patients	22 PFPS	Unclear	Turkey	Research center	Prospective cohort study	Isokinetic dynamometer (non-potrtable)
	Earl *et al*., 2011	Runners	19 PFPS	19 women	USA	Research center	Case series	Handheld dynamometer
	Sacco *et al*., 2006	Active patients	11 PFPS	8 men 13 women	Brazil	University hospital	Pre- and posttest intervention cohort study	No
Duplicates	**Van Linschoten *et al*. 2009** **Crossley *et al*., 2002** **Loudon *et al*., 2004** **Song *et al*., 2009** **Nakagawa *et al*., 2008** **Witvrouw *et al*., 2004**							
Howe *et al*., 2012	Marx *et al*., 2003	Athletic population	3 PFPS 67 other conditions	Unclear	USA	Clinic	Test retest	No
	Watson *et al*., 2005	unclear	21 PFPS 9 other conditions	80% women	USA	Clinic	Intra-subject	No
	Irrgang *et al*., 2001	Athletic patients	93/533 PFPS	47% women	USA	University	Unclear	No
	Irrgang *et al*., 2006	Athletic patients	19/207 PFPS	53% women	USA	University	Intra-, inter-subject between groups	No
	Bengtsson *et al*., 1996	Unclear	9/31 PFPS	Unclear	Sweden	Hospital	Intra-subject	No
	Piva *et al*., 2006	runners	30 PFPS	17 women 13 men	USA	University	Inter-tester	Hand-held dynamometer
	Laprade & Cullham, 2002	Military	29 PFPS	22 men 7 women	Canada	Force base	Intra-tester	No
	Chesworth *et al*., 1989	Unclear	18 PFPS	Unclear	Canada	Hospital	unclear	No
	Brosseau *et al*., 2001	N/A	60 healthy subject	44 women 16 men	Canada	University	Inter-tester	No
Duplicates	**Crossley *et al*., 2004** **Loudon *et al*., 2002** **Crossley *et al*., 2004**							
Esculier 2013	Kujala *et al*., 1993	Runners	16 PFPS 16 patellar dislocation 19 Patellar subluxation	All groups were women	Helsinki	Research institute	Cohort clinical trial	No

Systematic Review	Original Paper	Athletes/ Non-Athletes	No of Participants	Gender	Country	Setting	Study Design	Dynamometers
			17 controls					
	Harisson *et al*., 1995	Unclear	56 PFPS	Unclear	Canada	University	Test-retest	No
	MacIntyre *et al*., 1995	Unclear	10 PFPS	9 women 1 man 90% women	Canada	University medicine center	Unclear	No
	Irrgang *et al*., 1998	Unclear	78/397 PFPS	42% women	USA	University	Test-retest	No
	Bennell *et al*., 2000	Outpatients	50 PFPS	17 men 33 women 66% women	Australia	University	A repeated measures and correlational design	No
	Marx *et al*., 2001	Unclear	21/133 PFPS	48% women	USA	Hospital	Reliability, validity, and responsiveness	No
	Bizzini & Gorelick, 2007	Unclear	17/108	47% women	Switzerland	Hospital	Reliability, validity, cross-cultural adaption	No
	Higgins *et al*., 2007	Athletic patients	1517 non specified knee patients	41% women	USA	Sports medicine clinic	Validation study	No
	Lertwanich *et al*., 2008	Athletic patients	6/55 PFPS	2% women	Thailand	Unclear	Test retest study	No
	Heintjes *et al*., 2008	Unclear	314 non specified knee patients	46% women	Netherlands	Clinic	Prospective cohort	No
	Evcik *et al*., 2009	Outpatients	37/142 PFPS	86% women	Turkey	University	Adaption and validation study	No
	Piva *et al*., 2009	Mostly military	60 PFPS	33 women 27 men	USA	Air force bases	One group pre-post design	No
	Kuru *et al*., 2010	Unclear	40 PFPS	32 women 8 men	Turkey	University	Test-retest reliability study	No
	Metsavah, *et al*., 2010	Unclear	9/117 PFPS	69% women	Brazil	University	Cohort study	No
	Schmitt *et al*., 2010	Unclear	158/673 PFPS	54% women	USA	Hospital	Cohort study	No
	Cheung *et al*., 2012	Outpatients	64 PFPS	26 women 38 men	Hong-Kong	University	Translation and validation study	No
Duplicates	Negahban *et al*., 2012 **Irragang *et al*., 2001** **Chesworth *et al*., 1989** **Bengtsson *et al*., 1996** **Marx *et al*., 2003** **Crossley *et al*., 2003** **Watson *et al*., 2005** **Irrgang *et al*., 2006**	Unclear	100 PFPS	71 women 29 men	Iran	Research center	Translation and validation study	No