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International patellofemoral osteoarthritis consortium: consensus statement on the diagnosis, burden, outcome measures, prognosis, risk factors and treatment

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Abstract

Objective: To present the current status of knowledge in the field of patellofemoral (PF) osteoarthritis (OA) and formulate a research agenda in order to guide future research on this topic.

Design: A one-day meeting was organized with the aim to bring together international experts in the field to discuss the current state of knowledge on PF OA. Experts from multiple disciplines were invited based on their scientific publications in the field of PF OA and interest in the subject. Topics discussed include the diagnosis, impact, prognosis and treatment of PF OA.

Methods: Following context-setting presentations, an interactive discussion was held in order to achieve consensus on the PF OA topics of interest: 1) diagnosis and definition; 2) burden; 3) outcome measures; 4) prognosis; 5) risk factors and, 6) treatment. Groups of meeting attendees reviewed the literature on these topics and narratively summarized the current state of knowledge, and each group formulated research agenda items relevant to the specific topics of interest. Each consortium member consequently ranked the importance of all items on a 0-10 Numerical Rating Scale (NRS) (10 = extremely important, to 0 = not at all important).

Results: After ranking all formulated items on importance, six of the 28 research agenda items formulated received an average of 7.5 points on the NRS. The most highly ranked items covered the fields of treatment, diagnosis and definition of PF OA.

Conclusions: We recommend to develop clear clinical criteria for PF OA and to reach consensus on the definition of PF OA by both radiographs and MRI. Additionally, more understanding is necessary to be able to distinguish PF symptoms from those arising from the tibiofemoral joint. More insight is needed on effective treatment strategies for PF OA; specifically, tailoring non-pharmacological treatments to individuals with PF OA, and determining whether isolated PF OA requires different treatment strategies than combined PF and tibiofemoral OA.

Keywords

Patellofemoral * consensus * review* diagnosis * treatment * burden

1.0 Introduction

Osteoarthritis (OA) is a complex and multifactorial disease in which the knee is a frequently affected joint. The knee consists of three joints, the tibiofemoral (TF), patellofemoral (PF) and proximal tibiofibular joint, in which OA can occur in isolation or in combination. To date, most OA research effort has focused on the TF joint. This is surprising, since PF OA appears more prevalent and is a significant source of pain and associated disability [1]. In order to focus and progress research into the problem of PF OA, a one-day meeting (April 2016) was organized in Rotterdam, The Netherlands. The aim of the meeting was to bring together international experts in the field to discuss the current state of knowledge on PF OA. Experts of multiple disciplines (e.g. physiotherapy, rheumatology, orthopaedics, radiology, epidemiology, human movement sciences, general health sciences) were invited based on their scientific publications in the field of PF OA and interest in the subject. Topics that were discussed included the diagnosis, impact, prognosis and treatment of PF OA. Following some context-setting presentations, an interactive discussion was held in order to achieve consensus on the PF OA topics of interest: 1) Diagnosis and definition; 2) Burden; 3) Outcome measures; 4) Prognosis; 5) Risk factors and, 6) Treatment. Consequently, groups of meeting attendees were asked to review the literature on these specific topics and to narratively summarize the current state of knowledge. In addition, each group was tasked with formulating research agenda items relevant to the specific topics of interest. Each consortium member consequently ranked the importance of all items on a 0-10 Numerical Rating Scale (NRS) (10 = extremely important, to 0 = not at all important). We present here a position statement, including the current status of knowledge in the field of PF OA and a research agenda to guide future research on this topic.

2.0 Diagnosis and definition of PF OA

2.0.1 PREVALENCE AND INCIDENCE

A recent systematic review has described the prevalence of radiographically confirmed PF OA in different populations [2]. The prevalence was found to be 25% (95%CI 15-37%) in population-based cohorts and 39% (95%CI 25-54%) in symptom-based cohorts. Further analyses revealed that approximately half of the individuals with radiographic knee OA do have some degree of PF OA. In particular, females (aged ≥ 50 years) appeared to have a higher prevalence of PF OA (41%) compared to males (aged ≥ 50 years) (23%) [2]. The incidence of PF OA has been less frequently described in the literature with varying ranges reported: 4.6% in people (mean age 55.9 years, 80% female) with early OA symptoms within 5 years, compared to 28% in a 3-year period in a general older population (mean age 64.8 years, 51% female) [3,4]. Thus, the prevalence of PF OA appears to be high, with a substantial number of people having isolated PF OA (~40%). While the prevalence of isolated PF OA and combined OA in both the PF joint and TF joint appears to be similar [3,4], combined OA seems to be more prevalent than isolated PF OA in people with symptoms of knee pain [5-7]. The different prevalence rates of PF OA found across studies may be due to the different radiographic criteria applied, but may also reflect the diversity in populations studied [2].

2.0.2 IMAGING DEFINITION

Radiography has been the most frequently applied imaging technique used to diagnose and stage PF OA, although specific scoring systems for PF OA do not currently exist. The Kellgren and Lawrence[8] (KL) grading system is frequently used to define radiographic PF OA, especially in research settings[4,9,10], and relies on the presence of osteophytes and joint space narrowing. However, one should be aware that this method was originally developed for TF OA and that its validity for PF OA has not been assessed. Hence, it is unknown whether the KL grading system is in fact an appropriate tool to assess PF OA. Nevertheless, it has been shown that the sensitivity for detecting radiographic PF OA features is increased when specific radiographic projections of the PF joint are obtained, particularly skyline views[10,11]. It is therefore important to include a skyline view X-ray in order to detect osteophytes and joint space narrowing of the PF joint. In a recent systematic review of studies evaluating the prevalence of radiographic PF OA, it was found that most included studies used lateral and/or skyline views to define PF OA[12]. Some studies have used these two views in the supine position with the knee flexed to 45 degrees[10], while others have used weight bearing radiographs with 30 degrees of knee flexion for the lateral views and non-weight bearing skyline view radiographs with knees in 30 degrees flexion[4]. However, the impact of the knee position on the prevalence of radiographic findings remains unknown.

Magnetic resonance imaging (MRI) is increasingly performed in OA research because of its ability to directly visualize a range of joint tissues involved in PF OA, such as articular cartilage, synovium and fat pads. Several semi-quantitative MRI scoring methods exist, such as the MRI OA Knee Score (MOAKS)[13], which all include the PF joint as a sub-region. The presence, severity and location of several OA features on MRI have been related to PF OA symptoms[14]. An MRI definition of PF OA has been proposed requiring the presence of a definite osteophyte along the PF joint in combination with partial or full thickness cartilage loss[15], however the utility of this definition has not yet been explored.

2.0.3 CLINICAL DIAGNOSIS

In clinical practice, a clinical history and physical examination can yield information to identify knees with PF pain[16]. Stefanik et al.[17] found a sensitivity and specificity for the presence of isolated PF OA of 60% and 53%, respectively for the presence of anterior knee pain (pain on or around the patella) [17]. Absence of moderate pain while walking on level ground had the highest sensitivity (93%) but also the lowest specificity (13%). The combination of anterior knee pain and moderate pain with stair climbing had the highest specificity (97%), but low sensitivity (9%). Features from physical examination may enhance the ability to distinguish PF OA from TF OA. For example, crepitus (defined as hearable grinding noise and/or palpable vibrations in the knee detected by the hand of the investigator rested on the patella of the patient while squatting) was significantly associated with PF OA features seen on MRI, including cartilage lesions, osteophytes and bone marrow lesions, but not with features of TF OA[18]. Therefore the core clinical criteria to define PF OA should at least include the presence of anterior knee pain during weight bearing activities such as stair ambulation. An additional criterion could be the presence of crepitus.

There is urgent need to develop both clinical criteria and specific radiographic scoring systems for PF OA, which may enable definition of specific subgroups in future. Many studies have used radiographic features in order to define PF OA. However, a proportion of participants with defined radiographic PF OA do not have any knee pain or symptoms. We recommend that the definition of PF OA should include a combination of radiographic and clinical features.

2.0.4 RESEARCH AGENDA AIMS

- Develop clear clinical criteria for PF OA
- Determine how to isolate PF symptoms from those arising from the TF joint
- Reach consensus on the definition of PF OA for both radiographs and MRI
- Develop specific radiographic scoring systems for the patellofemoral joint

2.1 Burden of PF OA

2.1.1 SYMPTOMS AND IMPAIRMENTS

Symptoms and impairments associated with PF OA are not the same as those associated with TF OA [19,20]. Moderate to severe isolated PF OA may be characterized by a history of dramatic swelling, valgus knee deformity, pain on PF joint compression, and reduced quadriceps strength[20]. In the same study, clinical features of TF OA include effusion, bony enlargement, varus deformity, reduced knee flexion range of motion, and mediolateral instability[20].

Radiographic and MRI features of PF OA appear to have an independent impact on symptoms and disability[20], and to be more strongly associated with pain and functional limitations than imaging features of TF OA[6,21,22]. In people with knee pain, worsening radiographic severity of isolated PF OA is associated with worse scores on the pain, stiffness and function subscales of the Western Ontario and McMaster Universities Arthritis Index (WOMAC[23]) [1,4], crepitus with knee flexion[4], and stiffness after sitting or resting during the day[1,4]. While pain descending stairs is the functional task most strongly associated with severity of isolated PF OA, pain experienced when getting in and out of a bath or car, rising from bed, ascending stairs, and rising from sitting are also associated with PF OA[1]. The coexistence of PF OA with medial TF OA appears to result in worse pain ascending and descending stairs, compared to those with isolated medial TF OA[24].

MRI features of PF OA have been shown to predict worsening of patient-reported pain, symptoms, function and quality of life over two years, in an at-risk population who have undergone anterior cruciate ligament (ACL) reconstruction[25]. Importantly, the presence of PF OA has implications for the health of other knee joint compartments. The PF joint is often the first knee compartment affected by OA, and isolated symptomatic PF OA increases the risk of future TF OA development[3].

Although no studies have investigated measures of personal burden in people with PF OA, baseline data from clinical trials highlight the personal burden of PF OA when compared to published normative values. Two studies used the Knee injury and Osteoarthritis Outcome Score (KOOS), in

126 people (mean age 55 years)[9] and 92 people (age 55 years)[26] with PF OA. Figure 1 highlights deficits across all KOOS subscales in people with PF OA compared to normative values[27]. However, this is especially evident for the knee-related quality of life subscale, which is markedly lower in people with PF OA.

2.1.2 SOCIETAL BURDEN

PF OA has only recently been recognized as a distinct subgroup of knee OA[19]. It is therefore not surprising that the societal burden of PF OA has not been evaluated (e.g. quality adjusted life years, financial costs). While numerous studies have quantified the burden of general knee OA[28-30], it cannot be assumed that these findings apply to predominant or isolated PF OA. Not only are PF OA symptoms and impairments different to TFOA, but PF OA tends to affect younger adults than TFOA[31]. Considering that younger adults typically have greater responsibilities (e.g. occupation, child care), it is plausible that burden of disease measures, such as years lived with disability, would be higher in PF OA than TF OA.

2.2.3 RESEARCH AGENDA

- Quantify the societal burden of PF OA using well-designed studies or existing cohorts
- Quantify the personal burden of PF OA by comparing people with PF OA and matched controls on measures of function, health-related quality of life, and work participation
- Determine and clarify how impairments associated with PF OA differ from those with TF OA

2.3 Outcome measures for PF OA

2.3.1 PATIENT REPORTED OUTCOME MEASURES (PROMS)

The OARSI have recommended a core set of outcome measures for knee OA [32-34]: pain, physical function and patient global assessment. Similar PROMS have been advised for patellofemoral pain [35]. However, up to now, no specific PROMS have been developed specifically for PF OA. Clinical trials in people with PF OA have used PROMs that are generic (e.g. pain visual analogue scale) or intended for general knee OA (e.g. Knee injury and Osteoarthritis Outcome Score [KOOS][36], WOMAC[23]) [9,26,37,38]. Because PF OA symptoms and impairments are not the same as tibiofemoral OA[19,20], PROMs intended for general knee OA may not have adequate content validity for PF OA. Furthermore, the measurement properties of these PROMs have not been evaluated in PF OA, which is problematic because measurement properties are population-specific[39]. Thus, we cannot make evidence-based recommendations for PROMs for PF OA at this time.

2.3.2 PHYSICAL PERFORMANCE MEASURES

OARSI have recommended a set of physical performance measures for individuals with hip or knee OA[34]. It was emphasized that these tests may be ideal for most OA populations, but may not be challenging enough for early-stage knee OA patients. Additionally, these tests have not specifically been tested in a PF OA population. Few physical performance measures have been examined in PF OA cohorts, despite recommendations to incorporate these into clinical and research

assessments[40]. A recent pilot study (n=8) examined the impact of PF OA on the Timed Up and Go Test and 50 foot Fast Paced Walk Test. Only Timed Up and Go performance was significantly different to healthy age-matched controls[41]. This is likely because, unlike the TF joint, the PF joint is not loaded during level walking. While Timed Up and Go has moderate construct validity in a knee OA cohort (including PF OA and/or TF OA)[42,43], no other measurement properties have been evaluated. As such, we need to know whether the currently recommended tests are also reliable, valid and sensitive in a PF OA population and whether other or additional physical performance are needed for PF OA patients.

2.3.3 STRUCTURAL OUTCOME MEASURES

Structural changes can be assessed using different imaging modalities. As already discussed above, the presence of osteophytes and joint space narrowing can be assessed on plain radiographs using the KL grade[8] or other more detailed methods[44-48], while alignment and joint space width can also be measured[49]. More sensitive MRI-based semi-quantitative scoring systems include WORMS[50], BLOKS[51] and MOAKS[13], which assess features such as bone marrow lesions, cartilage defects, infrapatellar fat pad, synovitis and effusion. However, the validity and sensitivity of these methods have only been thoroughly studied for general knee OA, and not specifically for PF OA. Promising quantitative MRI techniques enable assessment of cartilage composition, cartilage morphometry, morphological assessment of various tissues, patellar bone blood perfusion and the degree of bone remodeling[49,52-55]. These techniques are still under development, and require further validation, correlation with clinical and semi-quantitative measures, and standardization.

2.3.4 OTHER (E.G. BIOCHEMICAL BIOMARKERS)

Some soluble OA biomarkers have been associated with the prediction of the onset and progression of OA.[56] These can be acquired from biological fluids including serum, synovial fluid and urine, and provide a perspective on the physiologic state of joint tissues. It is important to note that serum and urine markers reflect total body turnover and are not restricted to the joint of interest. To be clinically useful these biomarkers need further qualification studies.

2.3.5 RESEARCH AGENDA AIMS

- Development of PF OA-specific PROMs
- Evaluation of measurement properties of appropriate existing PROMs in people with PF OA
- Validation and assessment of reliability of currently recommended physical performance measures in populations with PF OA
- Development of PF OA-specific outcome measures for radiography and MRI
- Further development of quantitative imaging methods including validation, correlation with clinical and semi-quantitative scores and eventually standardization
- Further validation and qualification studies are required for soluble biomarker outcomes specific for PF OA

2.4 Prognosis

Few studies have reported on the natural history of PF OA, and those that have been conducted almost solely focus on structural progression assessed with radiographs or MRI.

Progression to radiographic PF OA in a population of middle-aged people with knee pain for more than 3 months was 31% over 6 years[57], and 17% over 3-years in people over 50 years with any knee pain in the last year[3]. The latter study also showed a 3-year cumulative progression of 19% of mild PF OA to moderate/severe PF OA; TF OA progression was 25% in the same cohort. Progression of the component radiographic features, joint space narrowing and osteophytes, was observed in a cohort study of people with unilateral meniscectomy[58] and in a prospective cohort study of people with early stage symptomatic knee OA[59]. In the meniscectomy cohort, 30% of people progressed one grade in their radiographic score of the index knee (5% in joint space narrowing; 27% in osteophytes) and 19% progressed one grade in the contralateral knee (7% in joint space narrowing; 15% in osteophytes) in 4 to 10 years. In the early knee OA population, PF progression of joint space narrowing and osteophytes was observed in 9.2% and 15.4% respectively; less frequently than in the TF joint (28.6% and 29.3% respectively)[59]. Thus, it appears that structural progression of PF OA occurs less frequently than TF OA, although limited studies report on the progression of PF OA separately from TF OA and combined knee OA. More importantly, no studies so far have reported on the clinical progression of PF OA.

The longitudinal inter-relationship between PF OA and TF OA has been described in multiple studies. Having TF OA was found to be a risk factor for onset and progression of PF OA in 3 or more years, and having PF OA was a risk factor for developing TF OA, both in knee pain populations using radiographic definitions[3,4], and in a female middle-aged population using MRI definitions[60]. A cohort of people with meniscectomy showed that 24% with unilateral TF OA, and 14% with unilateral PF OA, had bilateral radiographic disease 4-10 years later[58]. In the early OA knee cohort, the six-year radiographic progression of joint space narrowing and osteophytes in PF joint and TF joint were not related. However, there was an association between the progression of joint space narrowing and osteophytes of the PF joint and MRI features of medial TF joint[59]. So TF OA and PF OA seem inter-linked with each other, but future research needs to explore the relation between the joints more extensively.

In MRI studies that report the progression of cartilage volume loss in the PF joint, an annual 1.6% loss of cartilage volume was reported in a study population consisting of women (mean age 52 years) without clinical knee OA[61]. In two other studies consisting of patients with knee OA (both mean age 63 years) and radiographic evidence of knee OA (osteophytes and/or joint space narrowing) the annual loss of cartilage volume was 4.5% [62,63]. Women seem to lose patellar cartilage at a faster rate than men [62,63].

2.4.1 RESEARCH AGENDA

- What is the clinical trajectory of people with symptomatic PF OA?
- How are PF OA and TF OA inter-linked?

2.5 Risk factors for the onset and progression of PF OA

Several factors are hypothesized to alter the mechanics of the patellofemoral joint, leading to increased joint stresses, which can in turn lead to OA. These factors and impairments can be divided into four groups:

2.5.1 ABNORMAL PATELLOFEMORAL JOINT ALIGNMENT AND ABNORMAL TROCHLEAR MORPHOLOGY

One systematic review concluded that strong evidence supports the association between PF OA and both abnormal trochlear morphology and knee alignment (hip-knee-ankle angle and TF angle) in the frontal plane[64]. While longitudinal studies are still absent, there is limited evidence that malalignment in the sagittal plane (patella alta) and axial plane (lateral patellar displacement and tilt) are cross-sectionally associated with PF OA. However, an evidence gap remains regarding optimal measures and thresholds in these factors to optimize the prediction of PF OA. Therefore, future studies should assess both TF alignment (using posteroanterior radiographs[65]) and PF alignment (using skyline radiograph or MRI[64]).

2.5.2 KINETIC AND KINEMATIC ABNORMALITIES

Several studies have found that quadriceps muscle size[66], strength[20],[67] and force[68] is reduced in people with PF OA compared to people with no PF OA. Additionally, greater quadriceps strength has been found to be a protective factor against pain and cartilage loss over 30-months in the PF joint[69].

Weakness of muscle groups proximal to the knee (including but not limited to the glutei) have been extensively reported in young individuals with 'non-arthritis' PF pain, which has been suggested to be a precursor of PF OA[70-74]. Recent data suggest that compared to healthy controls, individuals with PF OA may also demonstrate proximal muscle dysfunction, including lower gluteus minimus and medius peak muscle force[75] and lower hip abductor strength[76]. However, these studies did not find differences between controls and patients in gluteus maximus peak muscle force[75] or hip external rotator strength[76]. Thus, in the absence of longitudinal evidence, the exact causal relationship between hip muscle weakness and PF OA remains unknown.

Altered joint mechanics may be important in disease onset, disease progression and symptom severity. Contradictory evidence suggests that abnormal biomechanics during gait can be observed in individuals with PF OA[68,75,77-79]. Pohl et al. reported that there were no differences in pelvis, hip and knee kinematics between people with PF OA and controls during level walking[76]. Folk et al. assessed stair ascent and descent which is more stressful to the PF joint and is a commonly reported functional problem.[68] They found those with PF OA had lower knee extension moments, quadriceps forces and PF joint reaction forces[68]. The only longitudinal study to date found that subjects who demonstrated higher peak knee flexion moments and flexion moment impulses, had progression of PF cartilage damage within 2 years[79]. Given limitations in skin marker-based technology systems for the PF joint, fluoroscopy or loaded imaging methodologies could be considered.

2.5.3 ACL RUPTURE AND RECONSTRUCTIONS

Previous studies have shown imaging evidence of PF OA following ACL injury and reconstruction[80-87], apparently unaffected by reconstruction using hamstring tendon or bone-patellar-bone autograft. The role of reconstruction in the development of PF OA is unknown[88]. It has been hypothesized that the development of PF OA is related to modified biomechanics which results in chondral damage[86,89]. ACL injury is also associated with worse symptoms and function[87], as well as deteriorating symptoms[25] of PF OA.

2.5.4 OTHER

Possible risk factors for progressive loss of patellar cartilage were age, BMI and more severe pain scores at baseline.[62,63] There is also a suggestion that exercise is associated with less patellar cartilage deterioration[12,61]. Known risk factors for progression of OA (woman, age, BMI) have shown to be risk factors for progression of PF cartilage deterioration. The presence of modifiable risk factors including obesity (using body mass index) and physical activity (using a validated accelerometer) should be assessed when possible in order to gain better insight into the role of these risk factors in the onset and progression of PF OA, since this is largely unknown.

2.5.5 RESEARCH AGENDA AIMS

- Identifying thresholds of measures of PF joint alignment and morphology that best predict PF OA
- Investigate the longitudinal relationship of joint alignment and morphology to worsening of PF OA
- Investigate the longitudinal relationship of abnormal gait mechanics to worsening of PF OA
- Investigate the longitudinal relationship of local and proximal muscle weakness to PF OA (cause or consequence)
- Investigate the aetiology of PF OA following ACL injury
- What are the risk factors for symptomatic and/or radiographic progression of PF OA?

2.6 Treatment

2.6.1 NON-PHARMACOLOGICAL NON-SURGICAL INTERVENTIONS

Clinical guidelines emphasize that OA treatments should be individualized to optimize clinical outcome[90] [91,92]. Although tailored treatment based on compartmental disease patterns seems appropriate, few studies have evaluated exercise and physical interventions specifically for patients with PF OA. Thus, there is limited evidence presently to guide management of PF OA (Table 1).

2.6.1.1 TAPING & BRACING

Patellar taping and bracing aim to reduce patellar malalignment. Two small cross-over studies in patients with PF OA evaluated the specific effects of taping. These studies showed that taping immediately reduces patellar malalignment and can reduce pain by 15%-25%[93,94]. The only randomized controlled trial (RCT) to evaluate taping in knee OA confirmed patellar taping reduced

pain and disability when applied for 3 weeks in 87 patients with mixed compartment OA, most with PF involvement[95]. However, given patients were not selected on the basis of radiographic or symptomatic PF OA, it is possible that taping may be even more effective in patients with predominant PF OA. It is unclear how taping achieves pain relief in PF OA. Research from younger people with PF pain suggests the pain relief may be due to subtle changes in patellar position that increase PF contact area and reduce PF joint stress[96,97]. However, this mechanism has not been evaluated in a population with PF OA.

Two studies have investigated the same patellar brace in PF OA with mixed results. Hunter et al [98] employed a double-blind RCT to evaluate a realigning PF brace compared to a non-realigning PF brace over 6 weeks in people with symptomatic, predominantly lateral, PF OA. Both braces led to pain reduction but with no difference between braces. Callaghan et al[9] compared the same realigning patellar brace to no brace in people with PF OA over a 6 weeks RCT. The brace used a realigning strap to seat the patella within the trochlea and people were given the option to use the re-aligning strap; 66% chose not to do so. The brace resulted in modest but significant pain relief, as well as the shrinking of PF bone marrow lesions. Since then, data have shown that in persons with PF OA this patellar brace alters patellar position and increases contact area between the patella and femoral trochlea[99]. But it is unclear whether benefits observed with bracing are due to non-specific (placebo) effects, re-alignment and/or compression of the patella.

2.6.1.2 COMBINED INTERVENTIONS

Two trials evaluated the efficacy of multi-modal physiotherapy programs for PF OA [26,37]. Quilty et al[37] used a Zelen RCT to test a complex package of interventions including thigh and hip muscle exercises, patellar taping, and advice regarding footwear and weight reduction. Findings showed no benefit compared to standard physiotherapy treatment for pain or function at 10 weeks, although the intervention group reported greater quadriceps strength. Crossley et al. (2015)[26] investigated a similar intervention program, but with more individual targeting of treatment elements and progressions (based on participant response). Compared to physiotherapy education alone, the treatment group reported significantly greater improvements in pain immediately following treatment cessation at 3 months, but benefits were not maintained 6 months later.

Relative to people with TF OA, there is a dearth of research investigating non-pharmacological non-surgical treatments for PF OA. Limited evidence suggests that either a complex package of physiotherapist-delivered interventions, or patellar taping or bracing in isolation, may immediately reduce pain associated with PF OA, but whether this is more effective than a more general intervention suitable for TF OA is not clear. There is also no evidence that any exercise or physical intervention for PF OA has lasting clinical benefits.

2.6.2 PHARMACOLOGICAL AND SURGICAL INTERVENTIONS

To our knowledge, there is only one surgical clinical trial specifically in a PF OA population, with this study evaluating the effectiveness of patellar resurfacing compared with patellar retention in a PF OA population with KL grade 4[100]. Despite the different methods of surgery, postoperative radiological assessment outcomes (patellar tilt, mechanical femorotibial angles and congruence angle) between the two groups were almost identical. Thus there is very limited evidence from

pharmacological trials (none so far) and surgical trials for the effectiveness of these interventions for PF OA.

2.6.3 RESEARCH AGENDA AIMS

- Determine the optimal and most cost-effective non-pharmacological treatment for people with PF OA via comparative effectiveness trials
- Evaluate if the presence of PF OA moderates short- and long-term OA treatment outcomes in people with combined compartmental patterns of OA
- Determine if people with isolated PF OA require different treatment strategies, including separate muscle strengthening strategies, to those with combined PF and TFOA
- Establish whether other biomechanical interventions (e.g. footwear, foot orthoses, tibial realignment braces) are effective for PF OA
- Determine if treatments can modify PF joint structure in those with PF OA in order to slow disease progression and improve long-term outcomes
- Determine moderators of outcome from non-pharmacological treatment in people with PF OA so that treatment regimens can be better tailored to the individual
- Determine if muscle strengthening or exercise can slow down the progression of cartilage loss in PF OA

3.0 Future directions

The PF OA expert group observed knowledge gaps in the research field of PF OA and formulated a research agenda, based on the narrative reviews performed by the consortium members. After ranking all formulated items on importance, six of the 28 research agenda items received an average of 7.5 points (the ten highest ranked items are presented in Table 2). The most highly ranked items covered the fields of treatment and diagnosis and definition of PF OA. We recommend to develop clear clinical criteria for PF OA and to reach consensus on the definition of PF OA by both radiograph and MRI. Additionally, more understanding is necessary in order to be able to isolate PF symptoms from those arising from the TJ joint. Clearly, more knowledge is needed on the clinical trajectory of people with PF OA and risk factors for symptomatic and/or radiographic progression of PF OA, since longitudinal studies investigating these are scarce. Evidently, more insight is needed in possible effective treatment strategies for PF OA; How can non-pharmacological treatments in people with PFOA be better tailored to the individual and do people with isolated PF OA require different treatment strategies? This implies that there is clearly need to evaluate moderators and effectiveness of treatment outcome in people with PF OA.

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References

1. Duncan R, Peat G, Thomas E et al. Does isolated patellofemoral osteoarthritis matter? *Osteoarthritis Cartilage* 2009; 17: 1151-1155
2. Kobayashi S, Pappas E, Fransen M et al. The prevalence of patellofemoral osteoarthritis: a systematic review and meta-analysis. *Osteoarthritis Cartilage* 2016; 24: 1697-1707
3. Duncan R, Peat G, Thomas E et al. Incidence, progression and sequence of development of radiographic knee osteoarthritis in a symptomatic population. *Ann Rheum Dis* 2011; 70: 1944-1948
4. Lankhorst NE, Damen J, Oei EH et al. Incidence, prevalence, natural course and prognosis of patellofemoral osteoarthritis: the Cohort Hip and Cohort Knee study. *Osteoarthritis Cartilage* 2017; 25: 647-653
5. McAlindon T, Zhang Y, Hannan M et al. Are risk factors for patellofemoral and tibiofemoral knee osteoarthritis different? *J Rheumatol* 1996; 23: 332-337
6. Duncan R, Peat G, Thomas E et al. How do pain and function vary with compartmental distribution and severity of radiographic knee osteoarthritis? *Rheumatology (Oxford)* 2008; 47: 1704-1707
7. Oniankitan O, Houzou P, Koffi-Tessio VE et al. [Patterns of osteoarthritis in patients attending a teaching hospital clinic]
Formes topographiques des arthroses des membres en consultation rhumatologique a Lome (Togo). *Tunis Med* 2009; 87: 863-866
8. Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. *Ann Rheum Dis* 1957; 16: 494-502
9. Callaghan MJ, Parkes MJ, Hutchinson CE et al. A randomised trial of a brace for patellofemoral osteoarthritis targeting knee pain and bone marrow lesions. *Ann Rheum Dis* 2015; 74: 1164-1170
10. Duncan RC, Hay EM, Saklatvala J et al. Prevalence of radiographic osteoarthritis--it all depends on your point of view. *Rheumatology (Oxford)* 2006; 45: 757-760
11. Heng HY, Bin Abd Razak HR, Mitra AK. Radiographic grading of the patellofemoral joint is more accurate in skyline compared to lateral views. *Ann Transl Med* 2015; 3: 263
12. Goldman LH, Tang K, Facchetti L et al. Role of thigh muscle cross-sectional area and strength in progression of knee cartilage degeneration over 48 months - data from the Osteoarthritis Initiative. *Osteoarthritis Cartilage* 2016; 24: 2082-2091
13. Hunter DJ, Guermazi A, Lo GH et al. Evolution of semi-quantitative whole joint assessment of knee OA: MOAKS (MRI Osteoarthritis Knee Score). *Osteoarthritis Cartilage* 2011; 19: 990-1002
14. Stefanik JJ, Gross KD, Guermazi A et al. The relation of MRI-detected structural damage in the medial and lateral patellofemoral joint to knee pain: the Multicenter and Framingham Osteoarthritis Studies. *Osteoarthritis Cartilage* 2015; 23: 565-570
15. Hunter DJ, Arden N, Conaghan PG et al. Definition of osteoarthritis on MRI: results of a Delphi exercise. *Osteoarthritis Cartilage* 2011; 19: 963-969
16. Felson DT. Challenges of identifying and treating patellofemoral osteoarthritis. *Br J Sports Med* 2016; 50: 832-833

17. Stefanik JJ, Neogi T, Niu J et al. The diagnostic performance of anterior knee pain and activity-related pain in identifying knees with structural damage in the patellofemoral joint: the Multicenter Osteoarthritis Study. *J Rheumatol* 2014; 41: 1695-1702
18. Schiphof D, van Middelkoop M, de Klerk BM et al. Crepitus is a first indication of patellofemoral osteoarthritis (and not of tibiofemoral osteoarthritis). *Osteoarthritis Cartilage* 2014; 22: 631-638
19. Hinman RS, Crossley KM. Patellofemoral joint osteoarthritis: an important subgroup of knee osteoarthritis. *Rheumatology (Oxford)* 2007; 46: 1057-1062
20. Peat G, Duncan RC, Wood LR et al. Clinical features of symptomatic patellofemoral joint osteoarthritis. *Arthritis Res Ther* 2012; 14: R63
21. Hunter DJ, March L, Sambrook PN. The association of cartilage volume with knee pain. *Osteoarthritis Cartilage* 2003; 11: 725-729
22. Kornaat PR, Bloem JL, Ceulemans RY et al. Osteoarthritis of the knee: association between clinical features and MR imaging findings. *Radiology* 2006; 239: 811-817
23. Bellamy N, Buchanan WW, Goldsmith CH et al. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. *J Rheumatol* 1988; 15: 1833-1840
24. Iijima H, Fukutani N, Aoyama T et al. Clinical Impact of Coexisting Patellofemoral Osteoarthritis in Japanese Patients With Medial Knee Osteoarthritis. *Arthritis Care Res (Hoboken)* 2016; 68: 493-501
25. Culvenor AG, Collins NJ, Guermazi A et al. Early Patellofemoral Osteoarthritis Features One Year After Anterior Cruciate Ligament Reconstruction: Symptoms and Quality of Life at Three Years. *Arthritis Care Res (Hoboken)* 2016; 68: 784-792
26. Crossley KM, Vicenzino B, Lentzos J et al. Exercise, education, manual-therapy and taping compared to education for patellofemoral osteoarthritis: a blinded, randomised clinical trial. *Osteoarthritis Cartilage* 2015; 23: 1457-1464
27. Paradowski PT, Bergman S, Sundén-Lundius A et al. Knee complaints vary with age and gender in the adult population. Population-based reference data for the Knee injury and Osteoarthritis Outcome Score (KOOS). *BMC Musculoskelet Disord* 2006; 7: 38
28. Peat G, McCarney R, Croft P. Knee pain and osteoarthritis in older adults: a review of community burden and current use of primary health care. *Ann Rheum Dis* 2001; 60: 91-97
29. Ackerman IN, Ademi Z, Osborne RH et al. Comparison of health-related quality of life, work status, and health care utilization and costs according to hip and knee joint disease severity: a national Australian study. *Phys Ther* 2013; 93: 889-899
30. Cross M, Smith E, Hoy D et al. The global burden of hip and knee osteoarthritis: estimates from the global burden of disease 2010 study. *Ann Rheum Dis* 2014; 73: 1323-1330
31. Hinman RS, Lentzos J, Vicenzino B et al. Is patellofemoral osteoarthritis common in middle-aged people with chronic patellofemoral pain? *Arthritis Care Res (Hoboken)* 2014; 66: 1252-1257
32. Bellamy N, Kirwan J, Boers M et al. Recommendations for a core set of outcome measures for future phase III clinical trials in knee, hip, and hand osteoarthritis. Consensus development at OMERACT III. *J Rheumatol* 1997; 24: 799-802
33. Altman R, Brandt K, Hochberg M et al. Design and conduct of clinical trials in patients with osteoarthritis: recommendations from a task force of the Osteoarthritis Research Society. Results from a workshop. *Osteoarthritis Cartilage* 1996; 4: 217-243
34. McAlindon TE, Driban JB, Henrotin Y et al. OARSI Clinical Trials Recommendations: Design, conduct, and reporting of clinical trials for knee osteoarthritis. *Osteoarthritis Cartilage* 2015; 23: 747-760

35. Crossley KM, Stefanik JJ, Selfe J et al. 2016 Patellofemoral pain consensus statement from the 4th International Patellofemoral Pain Research Retreat, Manchester. Part 1: Terminology, definitions, clinical examination, natural history, patellofemoral osteoarthritis and patient-reported outcome measures. *Br J Sports Med* 2016; 50: 839-843
36. Roos EM, Roos HP, Lohmander LS et al. Knee Injury and Osteoarthritis Outcome Score (KOOS)--development of a self-administered outcome measure. *J Orthop Sports Phys Ther* 1998; 28: 88-96
37. Quilty B, Tucker M, Campbell R et al. Physiotherapy, including quadriceps exercises and patellar taping, for knee osteoarthritis with predominant patello-femoral joint involvement: randomized controlled trial. *J Rheumatol* 2003; 30: 1311-1317
38. Hunter DJ, Harvey W, Gross KD et al. A randomized trial of patellofemoral bracing for treatment of patellofemoral osteoarthritis. *Osteoarthritis and cartilage / OARS, Osteoarthritis Research Society* 2011; 19: 792-800
39. Collins NJ, Prinsen CA, Christensen R et al. Knee Injury and Osteoarthritis Outcome Score (KOOS): systematic review and meta-analysis of measurement properties. *Osteoarthritis Cartilage* 2016; 24: 1317-1329
40. Dobson F, Hinman RS, Roos EM et al. OARSI recommended performance-based tests to assess physical function in people diagnosed with hip or knee osteoarthritis. *Osteoarthritis Cartilage* 2013; 21: 1042-1052
41. Høglund LT, Lockard MA, Barbe MF et al. Physical performance measurement in persons with patellofemoral osteoarthritis: A pilot study. *J Back Musculoskelet Rehabil* 2015; 28: 335-342
42. Dobson F, Hinman RS, Hall M et al. Measurement properties of performance-based measures to assess physical function in hip and knee osteoarthritis: a systematic review. *Osteoarthritis Cartilage* 2012; 20: 1548-1562
43. Mizner RL, Petterson SC, Clements KE et al. Measuring functional improvement after total knee arthroplasty requires both performance-based and patient-report assessments: a longitudinal analysis of outcomes. *J Arthroplasty* 2011; 26: 728-737
44. Scott WW, Jr., Lethbridge-Cejku M, Reichle R et al. Reliability of grading scales for individual radiographic features of osteoarthritis of the knee. The Baltimore longitudinal study of aging atlas of knee osteoarthritis. *Invest Radiol* 1993; 28: 497-501
45. Altman RD, Gold GE. Atlas of individual radiographic features in osteoarthritis, revised. *Osteoarthritis Cartilage* 2007; 15 Suppl A: A1-56
46. Burnett S, Hart DJ, Cooper C et al. A Radiographic Atlas of Osteoarthritis. In; London: Springer Verlag 1994
47. Spector T, Cooper C, Cushnighan J et al. A Radiographic Atlas of Knee Osteoarthritis. . In; London: Springer Verlag; 1992.
48. Nagaosa Y, Mateus M, Hassan B et al. Development of a logically devised line drawing atlas for grading of knee osteoarthritis. *Ann Rheum Dis* 2000; 59: 587-595
49. Hunter DJ, Altman RD, Cicuttini F et al. OARSI Clinical Trials Recommendations: Knee imaging in clinical trials in osteoarthritis. *Osteoarthritis Cartilage* 2015; 23: 698-715
50. Peterfy CG, Guermazi A, Zaim S et al. Whole-Organ Magnetic Resonance Imaging Score (WORMS) of the knee in osteoarthritis. *Osteoarthritis Cartilage* 2004; 12: 177-190
51. Hunter DJ, Lo GH, Gale D et al. The reliability of a new scoring system for knee osteoarthritis MRI and the validity of bone marrow lesion assessment: BLOKS (Boston Leeds Osteoarthritis Knee Score). *Ann Rheum Dis* 2008; 67: 206-211
52. Seah S, Wheaton D, Li L et al. The relationship of tibial bone perfusion to pain in knee osteoarthritis. *Osteoarthritis Cartilage* 2012; 20: 1527-1533

53. Dyke JP, Synan M, Ezell P et al. Characterization of bone perfusion by dynamic contrast-enhanced magnetic resonance imaging and positron emission tomography in the Dunkin-Hartley guinea pig model of advanced osteoarthritis. *J Orthop Res* 2015; 33: 366-372
54. Kobayashi N, Inaba Y, Tateishi U et al. Comparison of ¹⁸F-fluoride positron emission tomography and magnetic resonance imaging in evaluating early-stage osteoarthritis of the hip. *Nucl Med Commun* 2015; 36: 84-89
55. Poot DHJ, van der Heijden RA, van Middelkoop M et al. Dynamic contrast-enhanced MRI of the patellar bone: How to quantify perfusion. *J Magn Reson Imaging* 2017; DOI: 10.1002/jmri.25817:
56. Kraus VB, Burnett B, Coindreau J et al. Application of biomarkers in the development of drugs intended for the treatment of osteoarthritis. *Osteoarthritis Cartilage* 2011; 19: 515-542
57. Thorstensson CA, Andersson ML, Jonsson H et al. Natural course of knee osteoarthritis in middle-aged subjects with knee pain: 12-year follow-up using clinical and radiographic criteria. *Ann Rheum Dis* 2009; 68: 1890-1893
58. Paradowski PT, Lohmander LS, Englund M. Osteoarthritis of the knee after meniscal resection: long term radiographic evaluation of disease progression. *Osteoarthritis Cartilage* 2016; 24: 794-800
59. de Lange-Brokaar BJE, Bijsterbosch J, Kornaat PR et al. Radiographic progression of knee osteoarthritis is associated with MRI abnormalities in both the patellofemoral and tibiofemoral joint. *Osteoarthritis Cartilage* 2016; 24: 473-479
60. Schiphof D, Oei EH, Waarsing EJ et al. Patello-Femoral Osteoarthritis at Baseline Is Predictive for Tibio-Femoral Osteoarthritis Five Years Later and Vice Versa. *Osteoarthritis Cartilage* 2015; 23: A225-A226
61. Wijayaratne SP, Teichtahl AJ, Wluka AE et al. The determinants of change in patella cartilage volume--a cohort study of healthy middle-aged women. *Rheumatology (Oxford)* 2008; 47: 1426-1429
62. Brennan SL, Cicuttini FM, Shortreed S et al. Women lose patella cartilage at a faster rate than men: a 4.5-year cohort study of subjects with knee OA. *Maturitas* 2010; 67: 270-274
63. Cicuttini F, Wluka A, Wang Y et al. The determinants of change in patella cartilage volume in osteoarthritic knees. *J Rheumatol* 2002; 29: 2615-2619
64. Macri EM, Stefanik JJ, Khan KK et al. Is Tibiofemoral or Patellofemoral Alignment or Trochlear Morphology Associated With Patellofemoral Osteoarthritis? A Systematic Review. *Arthritis Care Res (Hoboken)* 2016; 68: 1453-1470
65. Hinman RS, May RL, Crossley KM. Is there an alternative to the full-leg radiograph for determining knee joint alignment in osteoarthritis? *Arthritis Rheum* 2006; 55: 306-313
66. Hart HF, Ackland DC, Pandy MG et al. Quadriceps volumes are reduced in people with patellofemoral joint osteoarthritis. *Osteoarthritis Cartilage* 2012; 20: 863-868
67. Farrokhi S, Piva SR, Gil AB et al. Association of severity of coexisting patellofemoral disease with increased impairments and functional limitations in patients with knee osteoarthritis. *Arthritis Care Res (Hoboken)* 2013; 65: 544-551
68. Fok LA, Schache AG, Crossley KM et al. Patellofemoral joint loading during stair ambulation in people with patellofemoral osteoarthritis. *Arthritis Rheum* 2013; 65: 2059-2069
69. Amin S, Baker K, Niu J et al. Quadriceps strength and the risk of cartilage loss and symptom progression in knee osteoarthritis. *Arthritis Rheum* 2009; 60: 189-198
70. Nakagawa TH, Moriya ET, Maciel CD et al. Trunk, pelvis, hip, and knee kinematics, hip strength, and gluteal muscle activation during a single-leg squat in males and females with and without patellofemoral pain syndrome. *J Orthop Sports Phys Ther* 2012; 42: 491-501
71. Nakagawa TH, Moriya ET, Maciel CD et al. Frontal plane biomechanics in males and females with and without patellofemoral pain. *Med Sci Sports Exerc* 2012; 44: 1747-1755

72. Souza RB, Powers CM. Differences in hip kinematics, muscle strength, and muscle activation between subjects with and without patellofemoral pain. *J Orthop Sports Phys Ther* 2009; 39: 12-19
73. Dierks TA, Manal KT, Hamill J et al. Proximal and distal influences on hip and knee kinematics in runners with patellofemoral pain during a prolonged run. *J Orthop Sports Phys Ther* 2008; 38: 448-456
74. Willson JD, Davis IS. Lower extremity mechanics of females with and without patellofemoral pain across activities with progressively greater task demands. *Clin Biomech (Bristol, Avon)* 2008; 23: 203-211
75. Crossley KM, Dorn TW, Ozturk H et al. Altered hip muscle forces during gait in people with patellofemoral osteoarthritis. *Osteoarthritis Cartilage* 2012; 20: 1243-1249
76. Pohl MB, Patel C, Wiley JP et al. Gait biomechanics and hip muscular strength in patients with patellofemoral osteoarthritis. *Gait Posture* 2013; 37: 440-444
77. Farrokhi S, O'Connell M, Fitzgerald GK. Altered gait biomechanics and increased knee-specific impairments in patients with coexisting tibiofemoral and patellofemoral osteoarthritis. *Gait Posture* 2015; 41: 81-85
78. Stefanik JJ, Guermazi A, Zhu Y et al. Quadriceps weakness, patella alta, and structural features of patellofemoral osteoarthritis. *Arthritis Care Res (Hoboken)* 2011; 63: 1391-1397
79. Teng HL, MacLeod TD, Link TM et al. Higher Knee Flexion Moment During the Second Half of the Stance Phase of Gait Is Associated With the Progression of Osteoarthritis of the Patellofemoral Joint on Magnetic Resonance Imaging. *J Orthop Sports Phys Ther* 2015; 45: 656-664
80. Oiestad BE, Holm I, Engebretsen L et al. The prevalence of patellofemoral osteoarthritis 12 years after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2013; 21: 942-949
81. Keays SL, Newcombe PA, Bullock-Saxton JE et al. Factors involved in the development of osteoarthritis after anterior cruciate ligament surgery. *Am J Sports Med* 2010; 38: 455-463
82. Keays SL, Bullock-Saxton JE, Keays AC et al. A 6-year follow-up of the effect of graft site on strength, stability, range of motion, function, and joint degeneration after anterior cruciate ligament reconstruction: patellar tendon versus semitendinosus and Gracilis tendon graft. *Am J Sports Med* 2007; 35: 729-739
83. Frobell RB, Le Graverand MP, Buck R et al. The acutely ACL injured knee assessed by MRI: changes in joint fluid, bone marrow lesions, and cartilage during the first year. *Osteoarthritis Cartilage* 2009; 17: 161-167
84. Jarvela T, Paakkala T, Kannus P et al. The incidence of patellofemoral osteoarthritis and associated findings 7 years after anterior cruciate ligament reconstruction with a bone-patellar tendon-bone autograft. *Am J Sports Med* 2001; 29: 18-24
85. Culvenor AG, Collins NJ, Guermazi A et al. Early knee osteoarthritis is evident one year following anterior cruciate ligament reconstruction: a magnetic resonance imaging evaluation. *Arthritis Rheumatol* 2015; 67: 946-955
86. Culvenor AG, Cook JL, Collins NJ et al. Is patellofemoral joint osteoarthritis an under-recognised outcome of anterior cruciate ligament reconstruction? A narrative literature review. *Br J Sports Med* 2013; 47: 66-70
87. Culvenor AG, Lai CC, Gabbe BJ et al. Patellofemoral osteoarthritis is prevalent and associated with worse symptoms and function after hamstring tendon autograft ACL reconstruction. *Br J Sports Med* 2014; 48: 435-439
88. van Meer BL, Oei EH, Meuffels DE et al. Degenerative Changes in the Knee 2 Years After Anterior Cruciate Ligament Rupture and Related Risk Factors: A Prospective Observational Follow-up Study. *Am J Sports Med* 2016; 44: 1524-1533

89. Culvenor AG, Schache AG, Vicenzino B et al. Are knee biomechanics different in those with and without patellofemoral osteoarthritis after anterior cruciate ligament reconstruction? *Arthritis Care Res (Hoboken)* 2014; 66: 1566-1570
90. Centre NCG. Osteoarthritis. Care and management in adults. Clinical guideline CG177. Methods, evidence and recommendations. In. London; 2014
91. Fernandes L, Hagen KB, Bijlsma JW et al. EULAR recommendations for the non-pharmacological core management of hip and knee osteoarthritis. *Ann Rheum Dis* 2013; 72: 1125-1135
92. McAlindon TE, Bannuru RR, Sullivan MC et al. OARSI guidelines for the non-surgical management of knee osteoarthritis. *Osteoarthr Cartilage* 2014; 22: 363-388
93. Crossley KM, Marino GP, Macilquham MD et al. Can patellar tape reduce the patellar malalignment and pain associated with patellofemoral osteoarthritis? *Arthritis Rheum* 2009; 61: 1719-1725
94. Cushnaghan J, McCarthy C, Dieppe P. Taping the patella medially: a new treatment for osteoarthritis of the knee joint? *BMJ* 1994; 308: 753-755
95. Hinman RS, Crossley KM, McConnell J et al. Efficacy of knee tape in the management of osteoarthritis of the knee: blinded randomised controlled trial. *BMJ* 2003; 327: 135
96. Powers CM, Ward SR, Chan LD et al. The effect of bracing on patella alignment and patellofemoral joint contact area. *Med Sci Sports Exerc* 2004; 36: 1226-1232
97. Powers CM, Ward SR, Chen YJ et al. The effect of bracing on patellofemoral joint stress during free and fast walking. *Am J Sports Med* 2004; 32: 224-231
98. Hunter DJ, Harvey W, Gross KD et al. A randomized trial of patellofemoral bracing for treatment of patellofemoral osteoarthritis. *Osteoarthritis Cartilage* 2011; 19: 792-800
99. Callaghan MJ, Guney H, Reeves ND et al. A knee brace alters patella position in patellofemoral osteoarthritis: a study using weight bearing magnetic resonance imaging. *Osteoarthritis Cartilage* 2016; 24: 2055-2060
100. Eshnazarov KE, Seon JK, Song EK. Comparison of Radiological Assessments Patellar Resurfacing with Retention for Grade IV Osteoarthritis in Patellofemoral Joint accomplished Total Knee Arthroplasty. *Vestn Rentgenol Radiol* 2016; 97: 28-32
101. Quilty B, Tucker M, Campbell R et al. Physiotherapy, including quadriceps exercises and patellar taping, for knee osteoarthritis with predominant patello-femoral joint involvement: randomized controlled trial. *J Rheumatol* 2003; 30: 1311-1317
102. Callaghan MJ, Parkes MJ, Felson DT. The Effect of Knee Braces on Quadriceps Strength and Inhibition in Subjects With Patellofemoral Osteoarthritis. *J Orthop Sports Phys Ther* 2016; 46: 19-25

Tables and figures

Table 1: Summary of randomised controlled trials of non-pharmacological interventions for management of people with PF OA

Trial	Study design	Sample	Intervention	Control	Findings	Study quality†
Cushnaghan et al 1994 [94]	Cross-over – 3 day interval	N=14 (10 F) Mean age=70.4 (range 55-84)	Medial patellar taping or Lateral patellar taping. Tape worn for 4 days	Neutral patellar taping	Medial tape showed a significant reduction in pain compared to both lateral and neutral tape and was preferred by patients.	4
Quilty et al 2003 [101]	Zelen RCT	N=87 (sex NS) Mean age=66.8 (9.5) Intervention; 66.7 (11.2) Control	Education, quadriceps and functional exercises, patellar taping. 9 sessions over 10 weeks with a physiotherapist	Standard non-physiotherapy treatment	The intervention produced small improvements in knee pain and quadriceps muscle strength 10 weeks after the end of the treatment period. There were no between-group differences at 12 months.	8
Crossley et al 2009 [93]	Cross-over – immediate effects	N=14 (10 F) Mean age=53.3 (6.8)	Patellar tape-to apply a medial glide and medial and superior tilt to patellar plus unload fat pad	No tape	Patellar tape resulted in immediate significant reduction in patellar lateral displacement and increase in lateral tilt angle. Mean pain during squatting decreased with tape compared with no tape.	7
Hunter et al 2011 [98]	Cross-over with 6 week	N=80 (63 F) Mean age=61 (9)	BioSkin Patellar Tracking Q	BioSkin Patellar Tracking Q	No difference between groups for pain,	7

	washout period		brace with patellar realigning strap applied. 6 weeks of daily wear	brace without strap. 6 weeks of daily wear	function or stiffness outcomes.	
Crossley et al 2015 [26]	RCT	N=92 (53 F) Mean age=56 (10) Intervention; 53 (10) Control	PF joint-targeted exercise, education, manual therapy, patellar taping. 8 sessions over 12 weeks with a physiotherapist	OA education. 8 sessions over 12 weeks with a physiotherapist	The intervention resulted in more people reporting improvement and greater pain reduction than control at 3 months but not at 9 months.	7
Callaghan et al 2015 [9,102]	RCT	N=126 (72 F) Mean age =55.5 (7.5)	BioSkin Patellar Tracking Q brace with or without use of re-aligning strap depending on patient preference. 6 weeks of daily use.	No knee brace	Brace group had lower knee pain and reduced PF bone marrow lesion volume on MRI but not tibiofemoral volume than control group. Quadriceps maximum voluntary contraction did not differ between groups. Arthrogenic muscle inhibition decreased in the brace group compared with control but may be of questionable clinical relevance.	6

† rated using PEDro where scores range from 0-10 with 10 being highest methodological quality; NS=not stated; PF=patellofemoral; RCT=randomized controlled trial