The Non-Operative Treatment of Anterior Knee Pain

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Abstract: Anterior knee pain is a common presenting complaint, and in many cases no identifiable cause can be found. In these circumstances it is commonly known as anterior knee pain syndrome or patellofemoral pain syndrome. The management for this condition is most commonly non-operative. Treatment strategies include physiotherapy, pharmacotherapy, orthoses and combinations of the above. There are many described methods in the literature with a wide spectrum of outcomes, which in itself is testimony to the lack of any generally accepted gold standard of care for these patients. It is thus unclear to the health care professional treating these patients which is the best treatment to offer. In this review we aim to summarise historical and most up to date literature on the subject and in so doing allow the health care professional pick whichever treatment strategy they feel most beneficial and also provide a guide for appropriate patient education.

Keywords: Anterior knee pain, patellofemoral syndrome, physiotherapy, orthoses, pharmacotherapy.

INTRODUCTION

By definition anterior knee pain is a symptom and not a diagnosis although this term has been used widely across the literature to describe a clinical entity for which no specific cause can be found. In recognition of this other names for this condition have been described, which include anterior knee pain syndrome (AKPS) and patellofemoral pain syndrome (PFPS). Other synoynms that have been used include chondromalacia patella and patellar chondropathy, although these imply actual observable damage to cartilage, whereas AKPS and PFPS are terms to be used only in the absence of cartilage damage [1-4]. It is commonly accepted that AKPS is a diagnosis of exclusion, and as such demands careful clinical assessment and appropriate investigations before this diagnosis can be made.

Anterior knee pain is a common complaint presenting to a variety of health care providers including primary care physicians, physiotherapists, rheumatologists, sports medicine practitioners and orthopaedic surgeons. Annual person consulting prevalence rates (APCPRs) for patellofemoral disorders were recently calculated in a primary care setting study [5]. Of 57,555 adult patients registered in one year, 1,782 presented with a knee complaint, of which 303 were coded as patellofemoral disorders. Anterior knee pain was by far the most common diagnosis made (APCPR 37.2/10,000).

The predominant symptom is peripatellar or retropatellar pain which is often activity-related, for example ascending/descending stairs, squatting or sitting for prolonged periods of time. Other associated manifestations described include

functional deficit, crepitus and instability. There is a wide spectrum of diagnoses that can cause anterior knee pain, and the cited factors in the literature associated with anterior knee pain, PFPS, chondromalcia patella, patella instability and patellar malalignment number in excess of 50 [6]. This means that undertaking a literature review of the assessment and treatment of this condition can be challenging and misleading.

Multiple possible aetiologies exist that can cause anterior knee pain and there have been several classification systems proposed [7, 8]. A more recent classification system proposed by Witrouw *et al.* is a modification of these and is based on a consensus reached by the European Rehabilitation Panel, which was designed to serve predominantly as a guide for the non-operative treatment of anterior knee pain [9]. The emphasis is on careful clinical assessment and tailoring each individual's treatment. The main assessment categories include alignment, i.e. looking for evidence of femoral anteversion, genu valgus/recurvatum, internal tibial torsion, foot and ankle deformity, etc. Patellar position is another category. McConnell [10] proposes four elements to patellofemoral examination, which include patellar glide, antero-posterior tilt, medio-lateral tilt and rotation, although this system has been found to have moderate intra-rater and poor inter-rater reliability. Patellar mobility has been implicated as a risk factor for patellofemoral pain [11], although mobility testing has been used with variable success. Witrouw *et al.* advocate its use [9] although a more recent study [12] demonstrated only moderate levels of inter-rater reliability at best and concluded that the patellar mobility scale can't be used in isolation to diagnose PFPS. Peri-patellar soft tissue elements need to be examined carefully as well with particular attention to individual components of the extensor mechanism. Weakness of the quadriceps, hip flexors/

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abductors, isolated vastus medialis obliquus (VMO) hypotrophy, tight quadriceps, hamstrings, gastrocnemius or retinacular structures need to be confirmed or excluded. EMG analysis has also been used to determine abnormal firing patterns within and between individual muscle bellies.

A prospective study carried out by Thijs *et al.* investigated gait related risk factors for patellofemoral pain [13]. 84 military cadets were enrolled and force plate plantar pressure measurements were performed prior to the six week military training period. Patients with patellofemoral symptoms were diagnosed and registered. 36 cadets developed patellofemoral symptoms during the six week training period. They identified that these subjects had significantly more laterally distributed pressure on initial contact and slower maximal velocity of change of lateral to medial direction of centre of pressure during gait phase transition. Supination of the foot or heel varus may be implicated risk factors.

Ng *et al.* investigated the effects of voluntary and perturbation activities involving the knee on the temporal recruitment of VMO and VL musculature of the quadriceps [14]. Unexpected movements effectively stimulate a quadriceps reflex contraction and potentially recruit the quadriceps muscles in a more productive manner for patient rehabilitation. 23 patients with patellofemoral pain were included in the study. The tasks involved semi-squatting, tip-toeing and heel standing. They found that mean EMG onset time for VMO was slower than VL for voluntary movements but the opposite occurred during perturbation tasks. They reasonably concluded that perturbation activities may have a role in the rehabilitation of patients with PFPS.

Further EMG investigations identified significantly earlier contraction of lateral hamstring relative to medial hamstring during maximal voluntary isometric contractions in patients with anterior knee pain [15]. No significance was found in temporal activity patterns between VMO and VL. The proposed theory is that this muscle firing pattern may induce an increased external rotational torque on the tibia and cause lateral patellar tracking precipitating anterior knee pain.

Recent work identified a significant association between idiopathic anterior knee pain and hamstring tightness [16]. 34 patients with idiopathic anterior knee pain were age and gender matched with an asymptomatic control group of 34 subjects. At mean follow up of 20 months they found a statistically significant improvement in the physical component of the SF-36 outcome questionnaire, although half the patients didn't attend their physiotherapy sessions. They also found significant hamstring tightness and external hip rotation in patients relative to the control group. They concluded that their findings support a theory that idiopathic anterior knee pain is a self-limiting condition and is associated with hamstring tightness.

A widely recognised theory regarding AKPS is the possible presence of abnormal activity patterns between VMO and VL during quadriceps contraction in patients with anterior knee pain. A systematic review and meta-analysis of studies investigating the firing patterns of VMO and VL relative to each other was carried out in 2008 comparing these patterns in patients with the asymptomatic population

[17]. They found that there was a trend towards delayed onset of VMO activity relative to VL in AKPS patients, although significant heterogeneity between results was shown and no definitive conclusions could be drawn to substantiate or dismiss this theory.

The majority of cases are treated in a primary care setting, which infer the importance of clinical examination. However the efficacy of specialised tests and examination protocols that are commonly used is subject to debate and there are no validation studies for these techniques (mobility tests, Clarke's test, grind tests). Similarly there is no clear agreement in the literature regarding the efficacy of commonly used imaging modalities such as ultrasound, CT and MRI. Therefore to most accurately reach a diagnosis of exclusion referral to an experienced specialist is advised.

AKPS is most commonly treated conservatively. The options include physiotherapy, pharmacotherapy, orthotics, other modalities such as therapeutic ultrasound or a combination of the above. There is an abundance of studies in the medical literature that have investigated the above with a wide variety of results and conclusions.

PHYSIOTHERAPY

Many rehabilitation regimes exist for the treatment of AKPS. These include quadriceps strengthening, stretching, specific warm-up and warm-down sequences, core stability and hip strengthening. Muscle specific electrostimulation has also been described.

Quadriceps strengthening encompasses a range of techniques. The exercises can involve concentric (muscle shortening), eccentric (muscle lengthening), isotonic (constant strain without change in muscle length), isometric (knee position is constant), isokinetic (constant contraction through a range of movement at constant velocity) and plyometric (explosive muscle contraction) activities. Futhermore exercises can be subdivided into closed chain (foot in contact with another surface such as the floor or bicycle pedal) or open chain (foot is free) types. Generally eccentric exercises are closed chain involving cycles, step repetitions or squats. Open chain exercises are generally isotonic or isometric, e.g. straight leg raises.

Stretching exercises are an important component of physiotherapy for AKPS. These exercises are focused at loosening potentially tight anatomical structures that may in theory predispose to AKPS. Fully extending the knee against tight hamstrings, iliotibial band or gastrocnemius muscles can increase the patellofemoral joint reaction force and precipitate pain. Similarly tight quadriceps may lead to the same consquences in deep flexion. As far as can be seen there are still no studies that have clearly provided evidence for the above theories, which in principle are sound.

Below is a summary of the studies that have investigated the effects of physiotherapy on AKPS. Limitations on interpreting their findings are unfortunately high as there is such heterogeneity with regard to trial quality, variations in inclusion and exclusion criteria, dozens of different outcome measures, and different types and combinations of physiotherapy regimes, making a meta-analysis almost impossible. It is generally accepted that there is a paucity of high quality data available that can conclusively demonstrate

the overall efficacy of various physiotherapy protocols. It can be noted that most of the studies have low to modest numbers of patients at best, variably high drop out rates, inconsistent blinding of assessors, and maximum follow up of 12 months.

Clark's study in 2000 compared four treatment groups [18]. They received advice alone, advice and patellar taping, taping and supervised exercises (eccentric quadriceps strengthening) or exercises alone. They were followed up at 3 and 12 months. Pooling treatment groups to those receiving exercise and those not receiving exercise were compared using patient satisfaction, pain levels (visual analogue scores/VAS) and discharge rates as outcome measures. The exercise group did demonstrate a significantly higher patient satisfaction and discharge rate. At 3 months there was improvement but no significant difference between the two groups for pain levels, but significant improvement in pain was found at 12 months for the exercise group. However this finding is possibly confounded by the drop out rate of 10 at 3 months and 32 at 12 months.

McMullen's study in 1990 included 29 patients, who were divided into three groups receiving isokinetic exercises, static open-chain exercises or a waiting list control group [19]. The data was collected over a four week period and no follow up. Formal pain scores were not described although reported to be the same after four weeks across all treatment groups. A trend of higher functional improvement was shown with static exercises compared to isokinetic exercises. Patient numbers and length of study preclude any conclusive evidence.

Timm *et al.* compared the use of a progressive resistance brace during activities of daily living to no treatment in 100 patients using pain and functional scores as outcome measures, over a period of four weeks [20]. Significant improvements were seen in the resistance bracing group compared to the control group with respect to pain and functional outcome scores.

Harrison *et al.* compared 113 patients divided into three groups which received either home based quadriceps stretching and strengthening, supervised quadriceps stretching and strengthening or an eccentric muscle programme including patellar taping (McConnell regime) [21]. Serial follow ups were conducted up to 12 months, with 54 drop outs by the end of the study. Significant improvement in pain and function was shown overall in all three groups and also in the McConnell regime group and home exercise group compared to the supervised standard physiotherapy group. They concluded that any of the treatments could be successfully used.

Witrouw's study in 2000 compared closed chain (eccentric) exercises with open chain exercises [22]. 60 patients were included with no drop outs by the end of the three month study. Significant improvements were seen in VAS, Kujala patellofemoral functional scale (KPFS) [23] and quantitative squat and step scoring at five weeks and three months. No significant difference was found between groups.

A similar study by Gaffney *et al.* investigated 72 patients split into two groups comparing eccentric and isometric exercise with taping to concentric isometric exercises (essentially closed versus open chain exercises) [24]. This was carried out over a six week period, with 12 drop outs in total by six weeks. VAS were significantly improved for both groups with no discernible difference between them.

Stiene *et al.* included 33 patients in their study, comparing isokinetic to closed chain exercises over a period of eight weeks [25]. Outcome measures included retro step repetitions to failure. They showed an improvement in muscle strength for both treatment groups but significantly better in the closed chain group. However this was potentially compounded by significantly differing baseline retro step repetition values between groups (3.2 in the closed chain group compared to 2.5 in the open chain group).

Thomee *et al.* investigated the difference between eccentric and isometric exercises in 40 female patients over a 12 week training block, using presence/absence of pain during sports, jogging, heavy loading and during rest after activity as outcome measures [26]. Patients were followed up to 12 months. Significant improvements in outcomes were shown for both types of exercise but no significant difference between them.

A different approach was recently adopted by Earl *et al.* investigating the effects of core stability exercises and hip strengthening in female patients with PFPS [27]. This study was conducted on the theoretical basis that weakness of hip and core stabilisers can cause dynamic malalignment of the lower limb and predispose to PFPS (proposed by Powers in 2003). The supporting evidence came from a systematic review conducted by Prins and Van Der Wurff in 2009, investigating the evidence for and against the presence or absence of weak hip function in female patients with PFPS. 19 patients were enrolled in an eight week programme to improve core and hip muscle function, and amongst a number of outcome measures they included pain and functional ability. They demonstrated significant improvements in pain and function, although long term improvement is unknown, small numbers were included and no control group was used. Although promising definitive evidence is yet to be shown.

Coppack *et al.* describe a warm up and warm down routine as a prophylactic measure against the development of overuse anterior knee pain in military recruits [28]. This single-blinded randomised controlled trial included 1,502 subjects who underwent a 14 week physically arduous training program. 759 received four strengthening and stretching exercises during supervised training sessions. These included closed chain and gluteal strengthening exercises and stretching (isometric hip abduction, forward lunges, single-leg stepdowns, squats and stretches of the quadriceps, iliotibial band, hamstrings and gastrocnemius). 743 underwent routine warm up exercises. The outcome measure was the presence or absence of anterior knee pain in subjects over the 14 week period. Overall 3 patients from the intervention group and 25 from the control group were discharged for medical reasons, and no follow up beyond 14 weeks was carried out. 46 subjects developed anterior knee, of whom 36 were in the control group and the remaining 10 in the intervention group. They identified a 75% risk reduction of developing anterior knee pain using these simple exercises compared to their routine warm up exercises. Further breakdown regarding efficacy of

individual components of the new regime were not possible, but as a whole the routine worked. Despite an earlier systematic review of prevention of sports injuries (Aaltonen *et al.*, 2007), which reported that the evidence for stretching exercises for injury prevention is mixed, the authors of this trial felt that stretching exercises are justified.

ORTHOTICS

Orthotic adjuncts about the knee have been used in combination with the techniques described above. A variety of braces have been used and described in the literature again with variable efficacy. The more common of these include patellar taping which produces a medially displacing force on the patella, originally described by McConnell in 1986 [10], and Couman bandaging.

The use of orthotics in the management of idiopathic anterior knee pain has been extensively investigated. Their function varies according to the type of orthosis used and whether or not they are used in conjunction with physiotherapy exercises. There is conflicting evidence in the literature advocating the use of orthotics and below is a summary to date.

Kowall *et al.* investigated whether or not patellar taping improved outcomes, comparing two groups that each received the same exercises but one group used taping and the other didn't [29]. There were 25 patients in total assessed over a four week period. No significant difference was found between the two groups.

Aminaka and Gribble investigated the effects of patellar taping on perceived pain levels and dynamic postural control in patients with PFPS and compared the results with a control group [30]. There were 20 patients in each group and pain was measured using VAS following the Star Excursion Balance Test (SEBT). They found lower pain scores in taped patients with PFPS compared to those undergoing the test without patellar taping and improved SEBT performance. They concluded that further research is warranted on investigating the effect of patellar taping on neuromuscular control of the patellofemoral joint during dynamic activity.

Ng and Wong demonstrated a potentially deleterious effect on VMO contraction by patellar taping [31]. 16 patients with PFPS had EMG measured onset and amplitude of VMO and VL contraction. This was measured during a postero-anterior knee perturbation test and repeated measurements were taken in fatigued muscles following knee extension exercises. No significant differences were seen in temporal activation of VMO and VL muscles, although VMO amplitude was significantly lower in individuals with patellar taping.

A more recent systematic review and meta-analysis by Warden *et al.* examined the evidence for and against the use of patellar taping and bracing in patients with chronic anterior knee pain [32]. They included 16 trials, 13 of which involved patients with anterior knee pain and 3 for patients with osteoarthritis. Defining pain on a 100 mm scale, they showed that taping of the knee to exert a medially translating force on the patella reduced knee pain by 16.1 mm when compared to using no tape at all. They concluded that this was a clinically meaningful improvement in chronic knee pain patients. Regarding the use of braces the trials analysed

suffered from low methodological quality and as such the evidence from these was insufficient to demonstrate any significant benefit conferred by the use of bracing in these patients.

A Cochrane review is currently underway to examine the evidence for efficacy of patellar taping in anterior knee pain patients (Callaghan and Selfe).

Previous studies examining the effects of patellofemoral bracing in a military setting failed to demonstrate a positive effect of bracing in these patients. Finestone *et al.* investigated 59 subjects split into three groups treated with a patellofemoral brace, an elasticated knee sleeve or no orthosis at all over a two month period [33]. No advantage with bracing was found. A similar study by Miller *et al.* also used 59 patients who were divided into three groups receiving either a patellar realignment brace, an infrapatellar knee strap or no orthosis [34]. Again no significant improvement was found over a three week period.

Wiener-Ogilvie studied the effects of foot orthoses and physiotherapy on patients with anterior knee pain [35]. 31 patients were randomised to groups receiving either physiotherapy alone, physiotherapy and foot orthoses or foot orthoses alone. The physiotherapy included quadriceps strengthening, hamstring stretching exercises and dynamic side-stepping. Follow up was at four and eight weeks. Four patients were lost to follow up. No significant differences in outcome measures were shown amongst the three groups relating to function or pain levels.

A report by Vicenzo *et al.* commented on the lack of sufficient evidence in the literature supporting the use of foot orthoses in the conservative treatment of anterior knee pain and their group went on to publish the results of a prospective single blinded randomised clinical trial they conducted to investigate the efficacy of foot orthoses [36]. 179 subjects participated in the study all of who had a diagnosis of PFPS of more than 6 weeks duration. The patients were split into four groups, which each received either a foot orthosis, a flat insert, physiotherapy or physiotherapy and a foot orthosis. Flat inserts were used effectively as a placebo on the basis that the patient received a device that would not correct any malalignment. The physiotherapy included patellar mobilisation and patellar taping. Outcome measures included global improvement scores, pain scores including anterior knee pain scale and functional index questionnaires. Follow up was carried out at six weeks, three months and a year. Seven patients were lost to follow up and one patient died. They found improvements in all groups at 52 weeks for pain and function but no significant difference was found between foot orthoses and inserts, foot orthoses and physiotherapy, or between physiotherapy and foot orthoses against physiotherapy alone. They concluded that foot orthoses do not necessarily improve short or long term outcomes for patients with PFPS.

The same group went further to determine whether or not certain patient variables could be used to predict the efficacy of foot orthoses [37]. This was a posthoc analysis of one treatment arm of their randomised clinical trial, which included 42 patients who had received foot orthoses. Univariate analysis was used to identify potential predictor variables. These included age, height, pain severity, anterior

knee pain scale score, functional index questionnaire score, foot morphometry (described as mid-foot width difference between weight bearing and non-weight bearing) and overall orthosis comfort. Patient age greater than 25, height less than 165 cm, VAS less than 53.25 mm, and a difference in midfoot width of more than 10.96 mm were shown to be potentially useful variables that may be used to predict success or failure of foot orthoses in PFPS patients and thus be of possible benefit when prescribing foot orthoses for these patients.

A cohort study by Barton *et al.* evaluated the efficacy of unmodified prefabricated foot orthoses in patients with PFPS [38]. 60 patients were enrolled and the study took place over 12 weeks. Outcome measures included AKPS, lower extremity functional scale (LEFS), number of pain free step downs, number of single leg raises from sitting and usual and worst pain in the previous week. They found that significant improvements in step down and leg raise numbers were achieved. Significant improvement was also seen in usual and worst pain from previous week. AKPS and LEFS scores showed improvement although these were not significant. They concluded that the use of unmodified prefabricated foot orthoses may improve functional performance over time and may have implications for the prevention of osteoarthritis in some patients. However the potential association between anterior knee pain and patellofemoral osteoarthritis has been investigated in a systematic review by Thomas *et al.* [39]. Seven trials were included, one of which was a case-control study the primary purpose of which was to establish whether or not there is a link. They showed an odd's ratio of 4.4 (CI 1.8 -10.6) in favour of an association. Approximate estimates from the other low quality studies of annual risk of patellofemoral osteoarthritis in anterior knee pain patients varied from 0% to 3.4%. Thus however likely an association exists between anterior knee pain patients and osteoarthritis the high quality evidence for this is still lacking.

DRUG THERAPY AND ULTRASOUND

On the use of drug therapy for anterior knee pain there have been many trials assessing the effects of non-steroidal anti-inflammatory medication (NSAIDs) and steroids usually in combination with physiotherapy. Bentley's study compared aspirin to placebo for patients with chondromalacia patellae [40]. No significant differences were found between the two groups. Suter compared naproxen to placebo in 36 patients and although a significant improvement in symptoms was found no verification of the clinical relevance of this small difference was done [41]. None of these studies were long term and overall do not provide definitive evidence on the efficacy of NSAIDs for AKPS.

The usefulness of glycosaminoglycan polysulphate (GAGPS) injections for AKPS has been studied by Kannus [42] and Raatikainen, which were summarised in the Cochrane systematic review by Heintjes *et al.* [43]. These were reasonably high quality studies, which had conflicting data on the efficacy of injections. Another problem is that the injections were intra-articular in one study and intra-muscular in the other, thus direct comparisons are not possible.

A case study and randomised clinical trial were published last year on the use of botulinum toxin type A (Dysport) for patients with chronic anterior knee pain. Regarding the case study this was a 37 year old patient with chronic anterior knee pain associated with crepitus and lateral patellar tracking [44]. He underwent 12 weeks of VMO exercises and also a 150 unit Dysport injection into VL. His pain and functional scores improved considerably. Singer *et al.* included 24 patients in total in their trial [45]. 14 patients received a 500 unit Dysport injection into VL and were compared with 10 patients who received a placebo saline injection. Both groups received home exercises targeting VMO strength, and AKPS and VAS were main outcome measures. At 12 weeks significant improvements were seen in the disport group relative the saline group with regard to AKPS and pain on kneeling, squatting and walking. They concluded that dysport injections helped to achieve improved pain reduction and function in comparison to saline placebo in patients with chronic knee pain with quadriceps muscle imbalance.

A widely practised method of treatment is the use of therapeutic ultrasound to ease symptoms in AKPS patients. Although reported in many studies in the literature there has been only one randomised clinical trial [46]. 54 patients were incuded and divided into four groups receiving phonophoresis, iontophoresis, ice and ultrasound combined and finally ice alone. 24% of patients were lost to follow up. Comparing the last two groups, no statistically different results were found for pain and quadriceps strength outcomes.

CONCLUSION

It is established that chronic anterior knee pain is a common entity and can be known as AKPS or PFPS. The exact cause is still poorly understood and methods of assessment and classification exist to guide the practitioner on managing this condition. Several described non-operative treatments are commonly used. The mainstay of treatment is physiotherapy, of which there are many regimes that have been tried and tested. Most of the literature would suggest a benefit from physiotherapy, although definitive evidence is still lacking due to limitations from a paucity of high quality data. No gold standard for any particular regime seems to exist demonstrating significantly better results than the others. Often physiotherapy is used in conjunction with an orthosis, ranging from patellar taping to customised foot and knee orthotics. The literature provides conflicting evidence on the use of orthoses and there is still no clear answer as to whether these are truly of long term benefit or not. There is little data to substantiate the use of other treatments such as NSAIDs, glycosaminoglycans injections and therapeutic ultrasound. Botulinum injections may have a role to play although this would clearly require further research to establish. Given such a conflicting medley of views regarding the non-operative management of chronic anterior knee pain it is difficult to advise on the best treatment algorithm and as such at this time there is no right or wrong answer. Having reviewed the evidence the authors would advocate a careful clinical assessment, exclusion of readily recognisable and treatable pathology, a prophylaxis program for high risk patients, and both supervised quadriceps strengthening and stretching exercises for patients with

symptoms. We would not recommend prescribing orthoses, injections, NSAIDS or therapeutic ultrasound.

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CONFLICT OF INTEREST

Neither of the authors have a conflict of interest to declare in relation to the production of this manuscript.

REFERENCES

[1]   Arroll B, Ellis-Pegler E, Edwards A, Sutcliffe G. Patellofemoral pain syndrome. A critical review of the clinical trials on nonoperative therapy. Am J Sports Med 1997; 25(2): 207-12.

[2]   Thomee R, Augustsson J, Karlsson J. Patellofemoral pain syndrome: a review of current issues. Sports Med 1999; 28(4): 245-62.

[3]   Holmes WS, Clancy WG. Clinical classification of patellofemoral pain and dysfunction. J Orthop Sports Phys Ther 1998; 28(5): 299-307.

[4]   Wood L, Muller S, Peat G. The epidemiology of patellofemoral disorders in adulthood: a review of routine general practice morbidity recording. Prim Health Care Res Dev 2011; 12(2): 157-64.

[5]   Teitge RA. Patellofemoral pain syndrome a paradigm for current surgical strategies. Orthop Clin North Am 2008; 39(3): 287-311.

[6]   Arendt E. Anatomy and malalignment of the patellofemoral joint: its relation to patellofemoral arthrosis. Clin Orthop Relat Res 2005; (436): 71-5.

[7]   Witvrouw E, Werner S, Mikkelsen C, Van Tiggelen D, Vanden Berghe L, Cerulli G. Clinical classification of patellofemoral pain syndrome: guidelines for non-operative treatment. Knee Surg Sports Traumatol Arthrosc 2005; 13: 122-30.

[8]   Insall J. Patellar pain. Current concepts review. J Bone Joint Surg 1982; 66A: 147-153.

[9]   Fulkerson JP. Evaluation of the peripatellar soft tissues and retinaculum in patients with patellofemoral pain. Clin Sports Med 1989; 8: 197-202.

[10]   McConnell J. The management of chondromalacia patellae: A long term solution. Aust J Physiother 1986; 32: 215-23.

[11]   Wild JJ, Franklin TD, Woods GW. Patellar pain and quadriceps rehabilitation. Am J Sports Med 1982; 10: 12-5.

[12]   Sweitzer BA, Cook C, Steadman JR, Hawkins RJ, Wyland DJ. The inter-rater reliability and diagnostic accuracy of patellar mobility tests in patients with anterior knee pain. Phys Sportsmed 2010; 38(3): 90-6.

[13]   Thijs Y, Van Thiggelen D, Roosen P, De Clercq D, Witvrouw E. A prospective study on gait-related intrinsic risk factors for patellofemoral pain. Clin J Sport Med 2007; 17(6): 437-45.

[14]   Ng EC, Chui MP, Siu AY, Yam VW, Ng GY. Ankle positioning and knee perturbation affect temporal recruitment of the vasti muscles in people with patellofemoral pain. Physiotherapy 2011; 97(1): 65-70.

[15]   Patil S, Dixon J, White LC, Jones AP, Hui AC. An electromyographic exploratory study comparing the difference in the onset of hamstring and quadriceps contraction in patients with anterior knee pain. Knee 2011; 18(5): 329-32.

[16]   Patil S, White L, Jones A, Hui AC. Idiopathic anterior knee pain in the young. A prospective controlled trial. Acta Orthop Belg 2010; 76(3): 356-9.

[17]   Chester R, Smith TO, Sweeting D, Dixon J, Wood S, Song F. The relative timing of VMO and VL in the aetiology of anterior knee pain: a systematic review and meta-anaysis. BMC Musculoskelet Disord 2008; 9: 64.

[18]   Clark DI, Downing N, Mitchell J, Coulson L, Syzpryt EP, Doherty M. Physiotherapy for anterior knee pain: a randomised controlled trial. Ann Rheum Dis 2000; 59(9): 700-4.

[19]   McMullen W, Roncarati A, Koval P. Static and isokinetic treatments of chondromalacia patella: a comparative investigation. J Orthop Sports Phys Ther 1990; 12: 256-66.

[20]   Collado H, Fredricson M. Patellofemoral pain syndrome. Clin Sports Med 2010; 29(3): 379-98.

[21]   Timm KE. Randomized controlled trial of Protonics on patellar pain, position, and function. Med Sci Sports Exerc 1998; 30(5): 665-70.

[22]   Harrison EL, Sheppard MS, McQuarrie AM. A randomized controlled trial of physical therapy treatment programs in patellofemoral pain syndrome. Physiother Can 1999; 51(2): 93-106.

[23]   Kujala UM, Jaakkola LH, Koskinen Sk, Taimela S, Hurme M, Nelimarkka O. Scoring of patellofemoral disorders. Arthroscopy 1993; 9(2): 159-63.

[24]   Gaffney K, Fricker P, Dwyer T, Barrett E, Skibinski K, Coutts R. Patellofemoral joint pain: a comparison of two treatment programmes. Excel 1992; 8: 179-89.

[25]   Stiene HA, Brosky T, Reinking MF, Nyland J, Mason MB. A comparison of closed kinetic chain and isokinetic joint isolation exercise in patients with patellofemoral dysfunction. J Orthop Sports Phys Ther 1996; 24(3): 136-41.

[26]   Thomee R. A comprehensive treatment approach for patellofemoral pain syndrome in young women. Phys Ther 1997; 77(12): 1690-703

[27]   Earl JE, Hoch AZ. A proximal strengthening program improves pain, function, and biomechanics in women with patellofemoral pain syndrome. Am J Sport Med 2011; 39(1): 154-63

[28]   Coppack RJ, Etherington J, Wills AK. The effects of exercise for the prevention of overuse anterior knee pain: a randomized controlled trial. Am J Sports Med 2011; 39(5): 940-8.

[29]   Kowall MG, Kolk G, Nuber GW. Patellar taping in the treatment of patellofemoral pain. A prospective randomised study. Am J Sports Med 1996; 24: 61-6.

[30]   Aminaka N, Gribble PA. Patellar taping, patellofemoral pain syndrome, lower extremity kinematics, and dynamic postural control. J Athl Train 2008; 43(1): 21-8.

[31]   Ng GY, Wong PY. Patellar taping affects vastus medialis obliquus activation in subjects with patellofemoral pain before and after quadriceps muscle fatigue. Clin Rehabil 2009; 23(8): 705-13.

[32]   Warden SJ, Hinman RS, Watson MA Jr, Avin KG, Bialocerkowski AE, Crossley KM. Patellar taping and bracing for the treatment of anterior knee pain: a systematic review and meta-analysis. Arthritis Rheum 2008; 59(1): 73-83.

[33]   Finestone A, Radin EL, Lev B. Treatment of overuse patellofemoral pain. Prospective randomised controlled trial in military setting. Clin Orthop Relat Res 1993; 293: 208-10.

[34]   Miller MD, Hinkin DT, Wisnowski JW. The efficacy of orthotics for anterior knee pain in military trainees. A preliminary report. Am J Knee Surg 1997; 10(1): 10-3.

[35]   Wiener-Ogilvie S, Jones RB. A randomised trial of exercise therapy and foot orthoses as treatment for knee pain in primary care. Br J Podiatry 2004; 7(2): 43-9.

[36]   Vicenzo B, Collins N, Crossley K, Beller E, Darnell R, McPoil T. Foot orthoses and physiotherapy in the treatment of patellofemoral pain syndrome: a randomised clinical trial. BMC Musculoskelet Disord 2008; 9: 27.

[37]   Vicenzo B, Collins N, Cleland J, McPoil T. A clinical prediction rule for identifying patients with patellofemoral pain who are likely to benefit from foot orthoses: a preliminary determination. Br J Sports Med 2010; 44(12): 862-6.

[38]   Barton CJ, Menz HB, Crossley KM. Effects of prefabricated foot orthoses on pain and function in patients with patellofemoral pain syndrome: a cohort study. Phys Ther Sport 2011; 12(2): 70-5.

[39]   Thomas MJ, Wood L, Selfe J, Peat G. Anterior knee pain in younger adults as a precursor to subsequent patellofemoral osteoarthritis: a systematic review. BMC Musculoskelet Disord 2010; 11: 201.

[40]   Bentley G, Leslie IJ, Fischer D. Effect of aspirin treatment on chondromalacia patellae. Ann Rheum Dis 1981; 40(1): 37-41.

[41]   Suter E, Herzog W, De Souza K, Bray R. Inhibition of the quadriceps muscles in patients with anterior knee pain. J Appl Biomech 1998; 14(4): 360-73.

[42]   Kannus P, Natri A, Niittymäki S, Järvinen M. Effect of intraarti-cular glycosaminoglycan polysulfate treatment on patellofemoral pain syndrome - A prospective, randomized double-blind trial comparing glycosaminoglycan polysulfate with placebo and quadriceps muscle exercises. Arthritis Rheum 1992; 35(9): 1053-61.

[43]   Heintjes EM, Berger M, Bierma-Zeinstra SMA, Bernsen RMD, Verhaar JAN, Koes BW. Pharmacotherapy for patellofemoral pain syndrome. Cochrane Database Syst Rev 2004; (3): CD003470.

[44]   Drake DF, Pidcoe PE, Ericksen J. Botulinum toxin type A for nonsurgical lateral release in patellofemoral pain syndrome: a case study. Mil Med 2011; 176(6): 696-8.

[45]   Singer BJ, Silbert PL, Song S, Dunne JW, Singer KP. Treatment of refractory anterior knee pain using botulinum toxin type A (Dysport) injection to the distal vastus lateralis muscle: a randomised placebo controlled crossover trial. Br J Sports Med 2011; 45(8): 640-5.

[46]   Antich TJ, Randall CC, Westbrook RA, Morrissey MC, Brewster CE. Physical therapy treatment of knee extensor mechanism disorders: comparison of four treatment modalities. J Orthop Sports Phys Ther 1986; 8(5): 255-9.