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SYSTEMATIC REVIEW OF THE LITERATURE:

AN UPDATE FOR THE CONSERVATIVE MANAGEMENT OF PATELLOFEMORAL PAIN SYNDROME: *A SYSTEMATIC REVIEW OF THE LITERATURE FROM 2000 TO 2010*

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ABSTRACT

Purpose/Background: Patellofemoral pain syndrome (PFPS) is one of the most common and clinically challenging knee pathologies. Historically, clinicians have used a myriad of interventions, many of which have benefited some but not all patients. Suboptimal outcomes may reflect the need for an evidence-based approach for the treatment of PFPS. The authors believe that integrating clinical expertise with the most current scientific data will enhance clinical practice. The purpose of this systematic review is to provide an update on the evidence for the conservative treatment of PFPS.

Methods: The PubMed, CINAHL, and SPORTDiscus databases were searched for studies published between January 1, 2000 and December 31, 2010. Studies used were any that utilized interventions lasting a minimum of 4 weeks for subjects with PFPS. Data were examined for subject sample, intervention duration, intervention type, and pain outcomes.

Results: General quadriceps strengthening continues to reduce pain in patients with PFPS. Data are inconclusive regarding the use of patellar taping, patellar bracing, knee bracing, and foot orthosis. Although emerging data suggest the importance of hip strengthening exercise, ongoing investigations are needed to better understand its effect on PFPS.

Conclusions: Current evidence supports the continued use of quadriceps exercise for the conservative management of PFPS. However, inconsistent or limited data regarding the other interventions precluded the authors' ability to make conclusive recommendations about their use. Future investigations should focus on identifying cohorts of patients with PFPS who may benefit from the other treatment approaches included in this systematic review.

Keywords: foot orthosis, hip exercise, knee, patella bracing, patella taping, quadriceps exercise

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INTRODUCTION

Patellofemoral pain syndrome (PFPS) is one of the most common knee problems experienced by active adults and adolescents.[1] Dye[2] has described PFPS as an orthopedic "enigma" since it is one of the most challenging pathologies to manage. Historically, clinicians have used a myriad of interventions, many of which have little, if any, supporting evidence.[3]

Recently, much attention has focused on evidence-based practice. Sackett et al[4] have defined evidence-based medicine as the "conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients." They do not imply that clinicians make clinical decisions irrespective of past clinical experiences or practices. Rather, they emphasize the "integration of individual clinical expertise with the best available external clinical evidence from systematic research."[4]

Murray et al[3] determined that clinicians in a sports injury clinic implemented interventions based solely on personal experience in 44% of patients treated for PFPS. Moreover, clinicians used primary research evidence in only 24% of PFPS cases. These results provided preliminary data regarding the limited use of evidence-based medicine for this patient population.

Clinicians[1,5] believe that PFPS results from abnormal patella tracking that leads to excessive compressive stress to the patellar facets. Factors that may contribute to abnormal patella tracking include quadriceps weakness, quadriceps muscle imbalances, excessive knee soft tissue tightness, an increased quadriceps angle (*Q*-angle), hip weakness, and altered foot kinematics. Based on this clinical theory, the aim for interventions used for the treatment of PFPS is to improve patella tracking and reduce abnormal stress to patellofemoral joint structures.

Most patients with PFPS respond well to conservative interventions[6] and evidence[7,8] supports the use of exercise for the treatment of PFPS. Kettunen et al[9] recently compared outcomes for subjects with chronic PFPS who underwent arthroscopy followed by a home exercise program to similar subjects who only participated in a home exercise program. They found that all subjects, regardless of surgical or conservative treatment, reported similar significant functional improvements.

Researchers[10-13] have described many approaches for the conservative treatment of PFPS. Specific vastus medialis obliquus (VMO) and general quadriceps exercises represent the most commonly used intervention. Historically, clinicians have prescribed specific VMO exercises on the premise that a delay and/or reduction in VMO activity relative to the vastus lateralis (VL) contributes to excessive lateral patella tracking. Although evidence[14] questions selective VMO activation during exercise, general quadriceps strengthening does benefit many patients with PFPS and is considered the "gold" standard treatment.[7,15]

Other intervention strategies have incorporated patellar taping,[12,16] patellar bracing,[17] and knee bracing[18] to further improve patella tracking. Although most subjects reported decreased pain when using these techniques, they also performed quadriceps strengthening exercises. Moreover, findings from some studies inferred limited, if any, additional benefit with patella taping[16,19] or bracing[18] over quadriceps exercise alone.

Another popular belief regarding PFPS etiology is an increased *Q*-angle causing the quadriceps to exert a greater lateral force vector and predispose the patella to excessive lateral tracking.[20] This theory is not supported by the research findings, and many works[21-23] have found no relationship between an increased *Q*-angle and PFPS. Reasons for these findings may reflect the poor reliability and validity associated with this measure.[24] Another reason may reflect the static nature of this measure. Many patients with PFPS may demonstrate a normal *Q*-angle when assessed in a static manner. However, many of these patients may exhibit faulty lower extremity kinematics during dynamic activities like running, jumping, or single-leg landing that can increase the *Q*-angle.[22]

To address limitations with this static measure, Powers[22,25] has described use of the dynamic *Q*-angle since it assesses changes during dynamic, weight bearing activities. He has theorized that increased femoral adduction (relative to the pelvis) and/or femoral internal rotation (relative to the pelvis) during weight bearing activities can impart a valgus knee force and stress lateral patellofemoral joint structures. With the use of kinematic magnetic resonance imaging (MRI), preliminary evidence[26,27] has shown that subjects with PFPS demonstrated increased femoral internal rotation under a relatively stable patella during a single-leg squat. These findings provided a rationale for incorporating exercises that target the hip for patients with PFPS. Faulty foot mechanics also can affect the dynamic *Q*-angle. Tiberio[28] theorized that excessive subtalar pronation can cause increased tibial internal rotation. Excessive tibial internal rotation would then require a greater amount of relative femoral internal rotation to extend the knee (i.e., the screw-home mechanism) during weight bearing activities. Lee and colleagues[29,30] reported an association between increased lateral patellofemoral joint stress and excessive femoral internal rotation. Based on these findings, researchers have examined the use of hip strengthening[10,31,32] and foot orthosis use[33-35] for the treatment of PFPS.

Quadriceps strengthening exercise is the most commonly prescribed intervention. Although this approach may represent the therapist perceived "gold" standard, many patients continue to experience pain and dysfunction.[11,36] This cohort of patients who may report a decrease, but not total resolution of pain following quadriceps exercise, may reflect the need to identify other evidence-supported strategies. Therefore, the purpose of this literature review is to provide an update on the evidence for the conservative treatment of PFPS. It is our intent that clinicians use information gained from this review for the development and implementation of evidence-based practice for this patient population.

METHODS

Data Sources

An electronic search was performed on PubMed, CINAHL, and SPORTDiscus databases from January 1, 2000 to December 31, 2010 using the following key words (either in isolation or in combination): patellofemoral pain syndrome, anterior knee pain, quadriceps exercise, quadriceps strength, hip exercise, hip strength, tape, taping, brace, bracing, orthosis, orthotics, and orthoses. A combined total of 878 articles were identified from the above-named data bases for review (Table 1).

Table 1. *Search strategy of PubMED, CINAHL, and SPORTDiscus from January 1, 2000 through December 31, 2010 to identify potential articles eligible for inclusion in the systematic review (all terms were separately entered into each database).*

	Key Words	PubMed	CINAHL	SPORTDiscus
1	Patellofemoral pain syndrome or anterior knee pain	1,230	579	938
2	Quadriceps exercise or strength	1,270	46	25,220
3	Hip exercise or strength	2,013	9	25,791
4	Tape or taping	4,220	1,839	2,014
5	Brace or bracing	2,341	876	1,214
6	Orthosis or orthotics or orthoses	3,433	3,046	2,036
7	1 and 2	46	11	170
8	1 and 3	32	1	167
9	1 and 4	41	79	49
10	1 and 5	55	16	57
11	1 and 6	57	60	37
	Total potential articles to be included in the systematic review	231	167	480

Study Selection

The authors selected evidence consistent with current relevant practice. To do this, the original search for evidence was limited and included only peer-reviewed manuscripts published within the past 10 years that utilized interventions lasting a minimum of 4 weeks. Studies not written in English, conference abstracts, theses, and dissertations were also excluded. Each researcher initially identified potential articles based on the abstract and confirmed appropriate inclusion by reviewing each article. The researchers discussed their search findings to ensure identification of relevant articles. Based on these criteria, the authors found 22 acceptable articles.

Data Extraction

The following data were extracted from each article: subject sample, intervention duration, intervention type, and pain outcomes. The authors also identified the research design used for each study (e.g., case study, quasi-experimental, or randomized control trial).

Data Synthesis

The quality of each study was evaluated using guidelines described by Ebell et al,[37] who rate evidence for individual studies using a 3-level tier (Figure 1). The authors chose this taxonomy because it is patient-focused and allows the user to evaluate both a body of evidence and individual studies.

According to the Philadelphia Panel Evidence-Based Clinical-Practice Guidelines,[38] pain represents an important impairment associated with PFPS and was the one impairment consistently reported in all the identified studies. Therefore, changes in pain were used as the benchmark for assessing and comparing study results. Using the available data from each article, the percentage change on a visual analog scale was calculated that best represented usual pain (e.g., pain normally experienced over a week[39]), and the associated effect size for each intervention group was also reported (see Tables 2-6). Effect sizes were interpreted in the following manner:[40] weak less than 0.40, moderate between 0.41 and 0.70, and strong greater than 0.70.

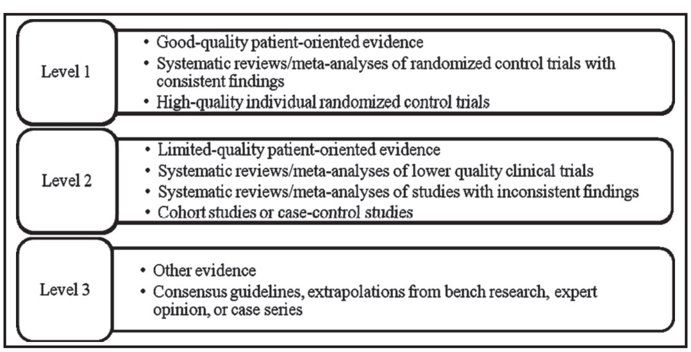

Figure 1. *Strength of Recommended Taxonomy (SORT) model[37] used to evaluate the current evidence for the treatment of patients with patellofemoral pain syndrome.*

RESULTS

Hip Strengthening Exercise

Five investigations (Table 2) specifically examined the use of hip strengthening for the treatment of subjects with PFPS. With the exception of the case study[31] (Level 3 evidence), all met the criteria for a Level 2 evidence rating and provided sufficient data to calculate effect sizes for changes in usual pain. Results from all the studies showed that subjects who participated in an exercise program targeting the hip abductors and hip external rotators reported at least a moderate reduction in pain (effect sizes ranging from 0.54 to 0.62). Additionally, Tyler et al[10] included hip extensor and hip flexor exercises and reported an even greater improvement in pain (effect size = 0.96).

Quadriceps Strengthening Exercise

Ten investigations (Table 3) met the inclusion criteria and all received a Level 2 evidence rating. Findings from most of the studies (8/10) suggested at least a moderate (effect size ranges ranging from 0.37 to 0.59) to strong (effect size ranges ranging from 0.83 to 0.93) improvement in pain when subjects performed either non-weight bearing or weight bearing quadriceps exercise. Although Syme et al[41] found that controls who received no intervention reported 17% less pain, this difference represented a weak improvement (effect size = .23).

Conversely, Bakhtiary & Fatemi[42] reported minimal changes in pain for subjects who performed either a supine straight leg raise exercise (effect size = 0.31) or a single-leg squat exercise (effect size = 0.24) protocol. It is noteworthy that their subjects performed a less demanding exercise program compared to others included in this review[11,41,43,44] (e.g., subjects in

Table 2. *Summary of intervention studies aimed at hip strengthening.*

Study, Type, Level of Evidence	Intervention	% decrease in usual pain	Effect Size
Boling et al[57] QE (Level 2)[a]	Weight bearing exercises that focused on quadriceps and hip abductor strengthening (1 group n=14)	50	.60
Fukuda et al[58] RCCT (Level 2)[a]	Group 1(n=23): knee exercise only	31	.28
	Group 2 (n=20): knee and hip abductor and lateral rotator exercise	42	.54
	Group 3 (n=21): control	-2†	.02
Mascal et al[31] CS (Level 3)[b]	Recruitment and endurance training of the hip, pelvis, and trunk muscles (2 subjects)	Subject A: 100 Subject B: 71	N/A
Nakagawa et al[32] RCPT (Level 2)[a]	Group 1(n=7): non-weight bearing and weight bearing quadriceps strengthening	15	.13
	Group 2 (n=7): same as above plus transversus abdominus, hip abductor, and hip lateral rotator strengthening	71	.62
Tyler et al[10] QE (Level 2)[a]	Non-weight bearing and weight bearing strengthening exercises designed to progressively strengthen the hip muscles (1group n=35)	45	.96

CS = case study
QE = quasi-experimental
RCPT = randomized controlled pilot trial
RCCT = randomized control clinical trial
PFPS = patellofemoral pain syndrome
N/A = unable to calculate since study design did not allow for reported means or standard deviations
a = Level 2 (limited-quality patient-oriented evidence)
b = Level 3 (other evidence)
† Represents an increase in pain

other investigations performed a higher exercise volume).

Some investigators incorporated quadriceps electrical stimulation[45] (effect size = 0.50), biofeedback[46] (effect size = 0.93), or simultaneous hip adductor activation[43] (effect size = 0.42) with exercise, all of which provided no additional benefit from quadriceps exercise alone. Loudon et al[13] only reported means but not standard deviations for their pain measures, which precluded our ability to calculate effect sizes. However, their subjects reported a 43% to 59% improvement in pain.

Patella Taping

Three studies (Table 4) that primarily used patella taping as an intervention met the established inclusion criteria. Crossley et al[12] conducted the only study that met the Level 1 evidence criteria. This study was a randomized control trial that compared outcomes between subjects who received a true intervention (specialized exercise and corrective patella taping) and those who received a placebo intervention (sham ultrasound and loosely applied tape). Subjects in the treatment group experienced a strong reduction in pain (effect size = 0.81). Although not expected to receive benefit from the placebo intervention, controls reported a moderate improvement in pain (effect size = 0.53). Studies by Clark et al[47] and Whittingham et al[48] received a Level 2 evidence rating. They found that subjects who participated in quadriceps exercise in combination with either correctly or loosely applied tape reported a moderate-to-strong reduction in pain (effect sizes ranging from 0.54 to 0.98).

Patella Bracing and Knee Bracing

Two studies, both with Level 2 evidence ratings, met our inclusion criteria for patella bracing and knee bracing (Table 5). Lun et al[17] found moderate improvements in

Table 3. *Summary of intervention studies aimed at quadriceps strengthening.*

Study, Type, Level of Evidence	Intervention	% decrease in pain	Effect Size
Bakhtiary & Fatemi[42] QE (Level 2)[a]	Group 1 (n=16): straight leg raise exercise	26	.31
	Group 2 (n=16): single-leg semi-squat exercise	26	.24
Bily et al[45] RCIT (Level 2)[a]	Group 1(n=18): combination of non-weight bearing and weight bearing hip and knee strengthening exercise[82]	75	.50
	Group 2 (n=18): same exercise program as above plus 2 20-minute daily sessions of electrical stimulation	73	.50
Dursun et al[46] RCT (Level 2)[a]	Group 1(n=30): combination of non-weight bearing and weight bearing quadriceps exercise and stationary bike plus biofeedback	84	.93
	Group 2 (n=30): same as group 1 except no biofeedback	90	.93
Hazneci et al[83] QE (Level 2)[a]	All subjects performed isokinetic knee extension exercise (1 group n=24)	52	.83
Herrington & Al-Sherhi[44] RCT (Level 2)[a]	Group 1(n=15): non-weight bearing knee extension exercise	44†	.56
	Group 2 (n=15): seated leg press exercise	61†	.83
	Group 3 (n=15): control	-20†β	.30
Loudon et al[13] RCT (Level 2)[a]	Group 1 (n=9): combination of non-weight bearing and weight bearing exercise performed in a PT clinic	59	N/A
	Group 2 (n=9): combination of non-weight bearing and weight bearing exercise performed as a home exercise program	43	
	Group 3 (n=11): control	8	
Song et al[43] RCT (Level 2)[a]	Group 1 (n=27): combined leg-press and hip adduction exercise	45	.42
	Group 2 (n=27): leg-press exercise	53	.48
	Group 3 (n=25): control	4	.04
Syme et al[41] RCT (Level 2)[a]	Group 1(n=21): selective vastus medialis oblique exercise	55	.43
	Group 2 (n=22): general quadriceps femoris exercise	45	.37
	Group 3 (n=20): control	17	.23
Witvrouw et al[11] RClT (Level 2)[a]	Group 1 (n=30): non-weight bearing knee extension exercise	47	.39
	Group 2 (n=30): weight bearing knee extension exercise	54	.43
Witvrouw et al[66] PR (Level 2)[a]	Group 1 (n=24): non-weight bearing knee extension exercise	71	.59
	Group 2 (n=25): weight bearing knee extension exercise	51	.45

QE = quasi-experimental
RCT = randomized control trial
RClT = randomized clinical trial
PR = prospective randomized
PFPS = patellofemoral pain syndrome
PT = physical therapy
N/A = unable to calculate since standard deviations were not reported
a = Level 2 (limited-quality patient-oriented evidence)
† Pain assessed using a 100-mm visual analog scale during a step-down test
β Represents an increase in pain

Table 4. *Summary of intervention studies incorporating patellar taping.*

Study, Type, Level of Evidence	Intervention	% decrease in pain	Effect Size
Clark et al[47] RCT (Level 2)[b]	Group 1 (n=16): exercise, taping, and education	53	.54
	Group 2 (n=16): exercise and education	61	.49
	Group 3 (n=18): taping and education	31	.32
	Group 4(n=21): education	21	.39
Crossley et al[12] RCT (Level 1)[a]	Group 1 (n=36): exercise program and patellar taping	77	.81
	Group 2 (n=35): placebo program (sham US and taping)	44	.53
Whittingham et al[48] RCT (Level 2)[b]	Group 1(n=10): patella taping and exercise program	100	.98
	Group 2 (n=10): placebo taping and exercise program	88	.97
	Group 3 (n=10): exercise program	76	.96

RCT = randomized control trial
PFPS = patellofemoral pain syndrome
PT = physical therapy
a = Level 1 (good-quality patient-oriented evidence)
b = Level 2 (limited-quality patient-oriented evidence)

Table 5. *Summary of intervention studies incorporating patellar and knee bracing.*

Study, Type, Level of Evidence	Intervention	% decrease in pain	Effect Size
Lun et al[77] QE (Level 2)[a]	Group 1 (n=34): home exercise program	48	.37
	Group 2(n=32): patellar bracing	52	.55
	Group 3 (n=32): home exercise program with patellar bracing	32	.27
	Group 4 (n=31): home exercise program with knee sleeve	47	.40
Denton et al[18] RCIT (Level 2)[a]	Group 1 (n=17): weight bearing quadriceps exercise	41% reported no pain during the step-up test at the end of the study	
	Group 2 (n=17): weight bearing quadriceps exercise and Protonics™ brace	100% reported no pain during the step-up test at the end of the study†	

QE = quasi-experimental
RCIT = randomized clinical trial
PFPS = patellofemoral pain syndrome
a = Level 2 (limited-quality patient-oriented evidence)
† Insufficient data reported to calculate % decrease in pain and effect size

pain with the use of either a patella brace (effect size = 0.55) or a neoprene knee sleeve (effect size = 0.40). In contrast to other findings[11,41,43,44] regarding quadriceps exercise, they also found limited support for a home exercise program (effect size = 0.37) or a home exercise program in combination with patella bracing (effect size = 0.27).

Denton et al[18] compared the use of the Protonics™ knee brace system to a traditional weight bearing quadriceps program. They did not assess pain in the same manner as the other studies (e.g. visual analog scale for usual pain) nor did they provide sufficient data to calculate effect sizes. However, Denton et al assessed pain during a step-down test (without bracing) and reported that subjects who performed exercise with the Protonics™ brace reported no pain during the step-down test following a 6-week intervention. Forty-one percent of the subjects who performed quadriceps exercise without the brace reported no pain during the same test.

Foot Orthosis

Collins et al[33] conducted the only randomized clinical trial (Level 1 evidence) to investigate foot orthosis use (Table 6). They divided a total of 157 subjects into one of the following groups: 1) corrective orthosis use and physical therapy exercise, 2) physical therapy exercise, 3) corrective orthosis use, and 4) flat insert use. Subjects who received corrective orthosis use and physical therapy exercise reported a moderate improvement in pain (effect size = 0.50). However, weak improvements in pain occurred in subjects who only received corrective orthosis use (effect size = 0.37) or physical therapy exercise (effect size = 0.35). Subjects who only wore a flat insole reported a 2% increase in pain (effect size = 0.02).

Johnston and Gross[49] examined the effect of foot orthoses on pain by issuing study participants custom-made foot orthoses. They assessed pain using the Western Ontario and McMaster Universities Arthritis Index (WOMAC) subscales of pain. All subjects reported decreased pain at the 3-month assessment period. The investigators did not provide sufficient data to calculate percentage changes in pain or effect sizes.

DISCUSSION

PFPS is one of the most common and most challenging knee pathologies to manage. Unlike anterior cruciate ligament injury, which has a specific mechanism of injury and treatment approach, patients with PFPS receive various interventions. Overall, this review of the existing evidence showed that many treatment strategies may benefit these patients. While quadriceps exercise remained an important intervention, this review also supported the addition of hip strengthening. Evidence for other popular interventions, such as patellar taping, patellar bracing, knee bracing, and foot orthosis prescription, appeared to be less efficacious than exercise alone. The following sections explain these findings and provide clinical suggestions for integrating current evidence into clinical practice.

Hip Strengthening Exercise

Computer simulation[50] and cadaveric models[29,30] have shown that excessive hip adduction and/or excessive hip internal rotation can stress lateral patellofemoral joint structures as these motion increase the force applied to this area. These findings have led to subsequent studies examining hip function in patients with PFPS. Souza and Powers[51] recently used traditional MRI to compare femoral structure (angle of inclination and torsion), muscle performance, and kinematics during running in this patient population. Overall, subjects with PFPS exhibited a 4.4° higher femoral angle of inclination but similar femoral anteversion as controls. They also demonstrated

Table 6. *Summary of intervention studies incorporating foot orthosis.*

Study, Type, Level of Evidence	Intervention	% decrease in pain	Effect Size
Collins et al[33] RCT (Level 1)[a]	Group 1 (n=39): orthoses and PT	51	.50
	Group 2 (n=41): PT	38	.35
	Group 3 (n=41): orthoses	34	.37
	Group 4 (n=36): flat inserts	-2§	.02
Johnston and Gross[49] OBS (Level 2)[b]	All subjects wore a fabricated orthosis (n=16)	All subjects demonstrated significant improvements in all 3 WOMAC subscales of pain†	

RCT = randomized control trial
OBS = observational study
PFPS = patellofemoral pain syndrome
PT = physical therapy
a = Level 1 (good-quality patient-oriented evidence)
b = Level 2 (limited-quality patient-oriented evidence)
† Insufficient data reported to calculate % decrease in pain and effect size
§ Subjects reported an increase in pain

hip weakness and greater femoral internal rotation during running, which they speculated would lead to increased lateral patellofemoral joint stress as shown in computer simulation[50] and cadaveric models.[29,30] Step-wise regression revealed that decreased isotonic hip extensor endurance, *not femoral structure*, was the only predictor of increased hip internal rotation. These findings highlighted the importance of hip muscle performance to control femoral motion and corroborated results from other investigations that have reported decreased hip strength and altered lower extremity kinematics in this patient population.[52-56]

The findings of the current review showed that hip strengthening exercise can benefit individuals with PFPS. Moderate evidence[32,57,58] supports the use of hip abductor and external rotator strengthening, which may be further enhanced with the inclusion of exercises targeting hip flexion[10] and hip extension.[10] Although all works prescribed exercise for strengthening effects (i.e., 3 sets of 10 to 15 repetitions), emerging evidence[51,56] has suggested the need to address muscle endurance. Therefore, clinicians should consider exercise dosage focusing on higher repetitions (i.e. 3 sets of 20 to 30 repetitions), especially in patients who participate in more demanding activities like running and jumping.

A limitation of most studies included in this review was a lack of attention toward neuromuscular factors such as activation amplitudes and timing differences between the hip and knee muscles. Preliminary evidence[59,60] has inferred a potential delay in gluteus medius activation relative to the quadriceps that could affect hip function. Future investigations should examine the role of neuromuscular factors as well as changes in these factors following a hip exercise program.[61]

Quadriceps Strengthening

Patients with PFPS historically have exhibited quadriceps weakness thought to contribute to abnormal patella tracking and patellofemoral joint irritation.[62] Another possible contributing factor may be a reduction and/or delay in VMO activity relative to the VL that can cause excessive lateral patella tracking. To date, conflicting findings have existed as some researchers[57,63,64] have reported a reduction and/or delay in VMO onset whereas others[59,65] have not corroborated this pattern. Even if VMO dysfunction exists, consistent data have not supported selective activation of the VMO during exercise.[14]

Findings agree with prior works regarding the importance of both weight bearing[11,66] and non-weight bearing[67-69] quadriceps strengthening for the treatment of PFPS. Consistent improvements in pain existed for subjects who performed general quadriceps strengthening exercises either in a weight bearing or non-weight bearing position. While clinicians may prefer weight bearing exercises that simulate functional activities, the use of non-weight bearing exercise may be equally beneficial, especially in patients with marked quadriceps weakness.

A key point to remember is that patients exercise in a pain-free manner.[15,70] Clinicians should consider biomechanical stresses applied to the patellofemoral joint during non-weight bearing and weight bearing exercise. Patellofemoral joint stress is less from 90 to 45 degrees of knee flexion during non-weight bearing exercise and less from 45 to 0 degrees of knee flexion during weight bearing exercise.[71] Finally, the additional use of neuromuscular electrical stimulation[45] or biofeedback[46] has no greater effect on pain than general quadriceps exercise alone.

Patella Taping

Patella taping is another intervention used to facilitate optimal patella alignment and tracking within the femoral trochlea. Often times, clinicians don tape to a patient's patella prior to exercise in hopes of decreasing pain and increasing VMO activation.

The results of this review support the use of taping in conjunction with exercise at least for the short-term treatment for PFPS. The mechanism by which patella taping may reduce symptoms remains elusive. Although initially theorized to improve patella alignment, prior works[72,73] have shown taping to be ineffective for maintaining alignment during or immediately following exercise. Therefore, subjects may benefit from taping for proprioceptive input or neuromuscular control during the time of use.[74]

Taping also may modulate pain[74] to enable a patient to perform pain-free quadriceps exercise. Using MRI to assess patella kinematics, Derasari et al[75] assessed

3 displacements (medial-lateral, superior-inferior, and posterior-anterior) and 3 rotations (lateral-medial tilt, extension-flexion, and posterior-anterior) in subjects with PFPS before and after McConnell taping. They found that taping primarily resulted in an inferior shift of the patella within the femoral trochlea. Increasing patella contact within the trochlea would reduce patellofemoral stress and may partially explain the positive results with tape use.

Interestingly, results from this review indicated that the manner of tape application (i.e. either applied in a corrective manner or applied loosely) may not necessarily influence its beneficial effects.[12,48] Therefore, taping may have an important effect on the neuromuscular system rather than actually altering patella movement.

The results of this review did not support the use of taping over exercise alone since exercise appeared to be an important factor.[12,13,47] It is noteworthy that taping has minimal effect in treating long-term symptoms associated with PFPS.[47] Therefore, clinicians may consider patella taping on a short-term basis as needed to enable patients to perform pain-free exercise.

Patellar Bracing and Knee Bracing

Similar to taping, clinicians have used both patellar and knee bracing to prevent or correct patella malalignment within the femoral trochlea. Powers et al[76] examined pain and patella contact area in subjects with PFPS who donned the On-Track® (DJO, Vista, CA) and Patellar Tracking Orthosis® (BREG, Inc., Vista, CA) patella braces. They reported that all subjects reported less pain with brace use and that MRI revealed increased patella contact area with brace use. Powers et al concluded that bracing may have shifted patella contact within the femoral trochlea from areas of irritation to non-irritation. These findings may explain why Lun et al[77] reported a moderate pain reduction in subjects who only wore a patellar brace.

The Protonics™ knee brace (Empi, St. Paul, MN) was the only knee brace included in this review. The brace was developed on the premise that iliopsoas and tensor fascia lata hypertonicity can lead to iliotibial band tightness and excessive lateral patella tracking.[78] Based on principles of reciprocal inhibition, the brace manufacturer designed the brace to promote hamstring activation in order to normalize iliopsoas and tensor fascia lata tone.

The brace also is designed to produce a variable degree of a knee-extension moment. The manufacturer theorizes that pain occurs from increased patellofemoral joint compression from quadriceps activity. The knee-extension moment generated from brace use enables patients to perform weight bearing activities in a pain-free manner by reducing the amount of the quadriceps-produced compressive force. As patients demonstrate less patellofemoral joint irritation, the brace can be adjusted to provide a lower knee-extension moment and require a greater degree of quadriceps activity.

The current findings suggest that the Protonics™ knee brace may be an effective intervention to reduce pain. Like patellar taping, the exact mechanism for improvement remains unclear. Possible reasons for favorable outcomes may include redistributed patella stress, enhanced proprioceptive input, and improved neuromuscular control that allow subjects to perform pain-free quadriceps exercise. Additional studies are needed to conclusively determine the isolated benefits of the Protonics™ brace compared to pain-free exercise alone.[18]

Foot Orthosis

Although clinicians routinely prescribe foot orthoses to minimize faulty lower extremity kinematics, few researchers[33,49] have examined foot orthosis use for the treatment of PFPS over the past 10 years. Moreover, the exact mechanism for pain relief remains elusive.[79]

No study included in this review examined kinematic changes during or following foot orthosis use, which limits the authors' ability to determine an exact mechanism of change with wear. However, Barton et al[79] found very limited evidence for a foot orthosis to modify knee transverse plane kinematics for subjects with PFPS. Furthermore, prospective investigations[80,81] have found inconsistent findings regarding an absolute relationship between increased foot pronation and the development of PFPS. Boling et al[23] identified increased navicular drop as a significant risk factor for developing PFPS. These findings suggested that correction of excessive pronation would benefit this patient population. Conversely, Thijs and colleagues[80,81] reported ambulation in a less pronated foot position as a predictor of PFPS. They concluded that the inability of the lower extremity to attenuate impact shock may contribute more to PFPS etiology. In summary, data gained from prospective studies suggest that PFPS may develop from either excessive or limited pronation.

Additional studies are needed to determine if foot orthosis use minimizes pain due to changes in kinematics (excessive pronation), kinetics (shock attenuation), or a combination of both. Moreover, evidence is needed to identify a cohort of patients likely to benefit from a foot orthosis. While isolated foot orthosis use may benefit some patients with PFPS,[33,49] evidence gained from this systematic review suggests that orthosis use can augment the effects of exercise.[79]

Future Research

Results from this systematic review support the continued use of quadriceps exercise and the incorporation of hip strengthening exercise. However, no data exist that conclusively confirm the effectiveness of isolated hip exercise over isolated quadriceps exercise. The author's findings also showed that certain interventions may benefit some but not all patients with PFPS. Information gained from this systematic review highlights the need to determine the isolated effects of hip strengthening on PFPS as well as identify specific cohorts of patients who may benefit from a specific intervention.

CONCLUSION

The purpose of this systematic review was to provide an update on the evidence for the conservative treatment of PFPS. Quadriceps exercise continues to represent an important treatment strategy. The results of this systematic review also support the addition of hip strengthening exercise. Clinicians have used biofeedback, patella taping, and foot orthoses as interventions for this patient population, and findings from this systematic review suggest that these strategies may augment the benefits gained from quadriceps exercise. Insufficient data regarding patella bracing limits the authors's ability to make a recommendation for its use.

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