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RESEARCH ARTICLE

EFFECT OF ULTRASOUND THERAPY COMBINED WITH VASTUS MEDIALIS OBLIQUE STRENGTHENING EXERCISES IN PATELLOFEMORAL OSTEOARTHRITIS: AN INTERVENTIONAL STUDY

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ABSTRACT

Background: Patellofemoral osteoarthritis (PFOA) is a degenerative knee condition that causes pain, functional limitations, and impaired mobility. Physiotherapeutic interventions, including therapeutic ultrasound and targeted muscle strengthening, may offer symptomatic relief and improved joint mechanics. **Objective:** To evaluate the effects of ultrasound therapy combined with Vastus Medialis Oblique (VMO) strengthening exercises on pain, functional performance, and patellar stability in individuals with PFOA. **Methods:** Sixty participants clinically diagnosed with PFOA were assigned to one of two interventional groups. The experimental group received ultrasound therapy in addition to VMO-specific strengthening exercises, while the comparison group received general knee strengthening exercises without ultrasound. Both groups underwent a 6-week exercise program, with pre- and post-intervention evaluations. Outcomes included pain intensity (Visual Analog Scale), function (Kujala Anterior Knee Pain Scale), and clinical assessment of patellar tracking. **Results:** The group receiving ultrasound and VMO-specific exercises demonstrated greater improvement in pain scores (mean VAS reduction of 3.2 ± 0.6) and function (mean Kujala score improvement of 18.5 ± 4.1) compared to the comparison group ($p < 0.05$). Improved dynamic patellar tracking was also more prominent in the experimental group. **Conclusion:** The combination of ultrasound therapy and VMO-targeted strengthening appears to be an effective approach in the conservative management of patellofemoral osteoarthritis. This interventional strategy may reduce symptoms and improve joint mechanics better than general strengthening protocols alone.

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INTRODUCTION

Patellofemoral osteoarthritis (PFOA) is a degenerative joint condition that primarily affects the patellofemoral compartment of the knee, where the patella articulates with the femur. It is a common source of anterior knee pain, particularly among middle-aged and older adults. Epidemiological studies have reported that PFOA may be present in up to 40% of individuals with knee pain, indicating its substantial contribution to functional disability and reduced quality of life [1,2]. The condition is associated with cartilage degradation, subchondral bone changes, osteophyte formation, and synovial inflammation, leading to symptoms such as pain during stair climbing, squatting, and prolonged sitting, as well as stiffness and joint instability. Demographically, PFOA tends to have a higher prevalence in females than in males, often attributed to anatomical and biomechanical factors including a wider pelvis, increased Q-angle, and altered neuromuscular control [3]. Hormonal influences may also contribute to increased ligamentous laxity and reduced joint stability in females. Risk factors for PFOA include previous patellar dislocation, malalignment of the patella, muscle imbalances, obesity, aging, and repetitive stress on the knee joint. These factors culminate in a mechanical environment that fosters joint degeneration and symptom exacerbation. Conservative management remains the cornerstone of PFOA treatment,

especially in early to moderate stages. Non-surgical interventions are focused on symptom alleviation, functional improvement, and delaying disease progression. These include pharmacological options (e.g., NSAIDs), physical therapy, weight management, bracing, and activity modification [4]. Among these, physiotherapy plays a critical role, particularly therapeutic exercise aimed at correcting muscle imbalances and improving joint biomechanics. The Vastus Medialis Oblique (VMO) is a critical component of the quadriceps femoris group, located medially on the anterior thigh. Its anatomical orientation allows it to exert a medial stabilizing force on the patella, counteracting lateral displacement caused by the vastus lateralis and other lateral structures. The integrity of the VMO is essential for proper patellar tracking during dynamic activities [5,6]. Dysfunction of the VMO, manifested as delayed activation or weakness, can lead to increased lateral patellar tilt and displacement, contributing to abnormal joint loading and accelerated cartilage wear. Consequently, targeted VMO strengthening is considered an effective intervention to enhance knee stability and reduce patellofemoral joint stress [7]. Exercise programs aimed at strengthening the VMO typically involve terminal knee extension activities, biofeedback training, neuromuscular stimulation, and closed-chain kinetic exercises. Recent studies suggest that neuromuscular re-education and eccentric strengthening can be particularly beneficial for restoring VMO function. Additionally, the integration of proprioceptive training has shown promise in improving neuromuscular control and reducing joint instability.

Therapeutic ultrasound is a widely employed modality in the management of musculoskeletal conditions. Its physiological effects are mediated through mechanical vibration at high frequencies, which generates both thermal and non-thermal effects in the targeted tissues [8,9]. The thermal effects include increased tissue temperature, enhanced collagen extensibility, and improved blood flow. Non-thermal mechanisms involve cavitation and acoustic streaming, which promote cellular repair, modulate inflammation, and facilitate tissue regeneration. Ultrasound therapy has been shown to reduce pain and improve function in various types of osteoarthritis, including knee OA. However, its application specifically in the context of PFOA has received limited research attention. The lack of standardization in ultrasound parameters (e.g., frequency, intensity, duration) and treatment protocols further complicates the interpretation of existing findings. Nevertheless, preliminary evidence supports the use of ultrasound as an adjunct to therapeutic exercises, with potential synergistic effects in reducing pain and enhancing rehabilitation outcomes. The rationale for combining VMO strengthening with therapeutic ultrasound in the management of PFOA is grounded in their complementary mechanisms of action. While ultrasound targets inflammation and tissue healing, VMO strengthening addresses biomechanical deficiencies and neuromuscular control. Together, they may provide a comprehensive approach to symptom management by alleviating pain, improving functional mobility, and enhancing joint stability. Despite the individual benefits of these modalities, few studies have rigorously examined their combined effect in patients with PFOA. This gap in the literature underscores the need for well-designed clinical studies to evaluate whether this integrative approach yields superior outcomes compared to conventional physiotherapy alone. This study was therefore designed to investigate the effectiveness of a combined intervention involving therapeutic ultrasound and targeted VMO strengthening exercises in patients with patellofemoral osteoarthritis. The primary objectives were to assess changes in pain intensity, functional performance, and knee joint stability following a structured 6-week intervention program. A secondary aim was to compare these outcomes with those achieved through general knee strengthening exercises without adjunct ultrasound therapy. By addressing these research questions, this study seeks to provide evidence-based guidance for the conservative management of PFOA and highlight the potential of combined modalities in optimizing patient care.

MATERIALS AND METHODS

Study Design: This was a prospective, interventional study conducted over 12 weeks at a physiotherapy rehabilitation center.

Participants: Sixty individuals (aged 40–65 years) with a clinical diagnosis of PFOA participated in the study. Diagnosis was based on symptoms of anterior knee pain for at least 3 months, radiographic evidence of patellofemoral joint changes, and positive Clarke's and grind tests.

Inclusion criteria

- Age 40–65 years
- Pain during stair climbing, squatting, or prolonged sitting
- Willingness to participate in a 6-week rehabilitation program

Exclusion criteria

- History of knee surgery or trauma
- Inflammatory arthritis or other systemic musculoskeletal diseases
- Recent intra-articular injections

Group Allocation

Participants were divided into two intervention groups (30 per group) based on availability and consent. No randomization procedure was applied.

Intervention Protocol

Experimental Group

- **Ultrasound therapy:** Continuous mode, 1 MHz frequency, 1.5 W/cm² intensity, 7 minutes/session on the anterior knee
- **VMO Strengthening Exercises:** Straight leg raises, terminal knee extensions, wall sits, and step-down exercises focused on VMO activation (3 sets × 10 reps, 3 times/week for 6 weeks)

Comparison Group

- **General Exercises:** Straight leg raises, heel slides, bridging, and hamstring stretches (matched in frequency and duration to experimental group)

Outcome Measures

Measurements were taken before and after the 6-week intervention:

- **Pain intensity:** Visual Analog Scale (VAS)
- **Function:** Kujala Anterior Knee Pain Scale (AKPS)
- **Knee stability:** Clinical assessment of patellar tracking (e.g., dynamic medial/lateral glide, step-down test)

Statistical Analysis: Data were analyzed using SPSS v25. Paired t-tests assessed within-group changes. Independent t-tests compared outcomes between the groups. Significance was set at $p < 0.05$.

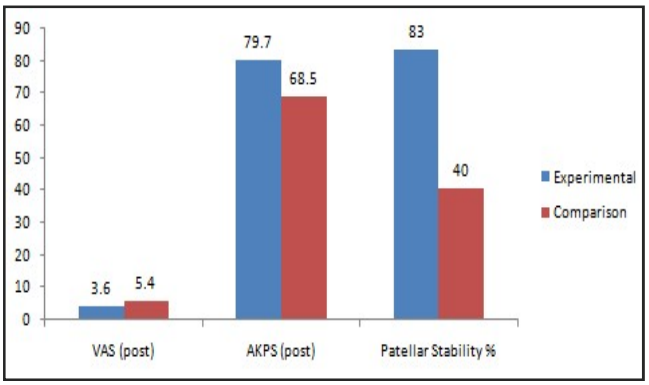
RESULTS

Participant Characteristics: All participants completed the study. No adverse effects were reported.

Characteristic	Experimental (n=30)	Comparison (n=30)	p-value
Age (mean ± SD)	53.4 ± 6.2	52.8 ± 5.9	0.72
Gender (F/M)	18/12	17/13	0.81
Baseline VAS	6.8 ± 1.1	6.7 ± 1.2	0.85
Baseline AKPS	61.2 ± 9.4	60.9 ± 10.1	0.88

Post-Intervention Outcomes

Outcome	Experimental	Comparison	p-value
VAS (post)	3.6 ± 0.7	5.4 ± 0.9	<0.001
AKPS (post)	79.7 ± 7.8	68.5 ± 8.3	<0.001
Patellar Stability	Improved in 83%	Improved in 40%	<0.01



Graph 3.1. Comparison of Post-Intervention Outcomes Between Experimental and Comparison Groups

The experimental group showed statistically and clinically significant improvements in all measures compared to the comparison group. The synergistic application of therapeutic ultrasound and vastus medialis oblique (VMO)-specific strengthening likely contributed to superior outcomes through multiple physiological pathways. Ultrasound therapy enhances local circulation, reduces inflammation, and promotes soft tissue healing via thermal and non-thermal effects, thereby addressing pain and joint irritation associated with patellofemoral osteoarthritis. Concurrently, targeted strengthening of the VMO—a key dynamic stabilizer of the patella—improves medial patellar tracking and reduces lateral displacement, enhancing patellofemoral joint alignment and load distribution during movement. Improved VMO activation also leads to better quadriceps coordination, reducing mechanical stress on the joint and improving functional tasks reflected in the AKPS scores. The combination of pain reduction (via ultrasound) and mechanical correction (via VMO training) likely explains the marked improvement in patellar stability reported by 83% of participants in the experimental group. In contrast, the comparison group did not receive the focused neuromuscular or adjunctive interventions necessary to induce these structural and functional adaptations, resulting in less pronounced clinical improvement.

DISCUSSION

Patellofemoral osteoarthritis (PFOA) is a degenerative joint condition that primarily affects the patellofemoral compartment of the knee, where the patella articulates with the femur. It is a common source of anterior knee pain, particularly among middle-aged and older adults. Epidemiological studies have reported that PFOA may be present in up to 40% of individuals with knee pain, indicating its substantial contribution to functional disability and reduced quality of life [1,2]. The condition is associated with cartilage degradation, subchondral bone changes, osteophyte formation, and synovial inflammation, leading to symptoms such as pain during stair climbing, squatting, and prolonged sitting, as well as stiffness and joint instability. Demographically, PFOA tends to have a higher prevalence in females than in males, often attributed to anatomical and biomechanical factors including a wider pelvis, increased Q-angle, and altered neuromuscular control [3]. Hormonal influences may also contribute to increased ligamentous laxity and reduced joint stability in females. Risk factors for PFOA include previous patellar dislocation, malalignment of the patella, muscle imbalances, obesity, aging, and repetitive stress on the knee joint. These factors culminate in a mechanical environment that fosters joint degeneration and symptom exacerbation.

Conservative management remains the cornerstone of PFOA treatment, especially in early to moderate stages. Non-surgical interventions are focused on symptom alleviation, functional improvement, and delaying disease progression. These include pharmacological options (e.g., NSAIDs), physical therapy, weight management, bracing, and activity modification [4]. Among these, physiotherapy plays a critical role, particularly therapeutic exercise aimed at correcting muscle imbalances and improving joint biomechanics. The Vastus Medialis Oblique (VMO) is a critical component of the quadriceps femoris group, located medially on the anterior thigh. Its anatomical orientation allows it to exert a medial stabilizing force on the patella, counteracting lateral displacement caused by the vastus lateralis and other lateral structures. The integrity of the VMO is essential for proper patellar tracking during dynamic activities [5,6]. Dysfunction of the VMO, manifested as delayed activation or weakness, can lead to increased lateral patellar tilt and displacement, contributing to abnormal joint loading and accelerated cartilage wear. Consequently, targeted VMO strengthening is considered an effective intervention to enhance knee stability and reduce patellofemoral joint stress [7].

Exercise programs aimed at strengthening the VMO typically involve terminal knee extension activities, biofeedback training, neuromuscular stimulation, and closed-chain kinetic exercises. Recent studies suggest that neuromuscular re-education and eccentric strengthening can be particularly beneficial for restoring VMO function. Additionally, the

integration of proprioceptive training has shown promise in improving neuromuscular control and reducing joint instability. Therapeutic ultrasound is a widely employed modality in the management of musculoskeletal conditions. Its physiological effects are mediated through mechanical vibration at high frequencies, which generates both thermal and non-thermal effects in the targeted tissues [8,9]. The thermal effects include increased tissue temperature, enhanced collagen extensibility, and improved blood flow. Non-thermal mechanisms involve cavitation and acoustic streaming, which promote cellular repair, modulate inflammation, and facilitate tissue regeneration. Ultrasound therapy has been shown to reduce pain and improve function in various types of osteoarthritis, including knee OA. However, its application specifically in the context of PFOA has received limited research attention. The lack of standardization in ultrasound parameters (e.g., frequency, intensity, duration) and treatment protocols further complicates the interpretation of existing findings. Nevertheless, preliminary evidence supports the use of ultrasound as an adjunct to therapeutic exercises, with potential synergistic effects in reducing pain and enhancing rehabilitation outcomes. The rationale for combining VMO strengthening with therapeutic ultrasound in the management of PFOA is grounded in their complementary mechanisms of action. While ultrasound targets inflammation and tissue healing, VMO strengthening addresses biomechanical deficiencies and neuromuscular control. Together, they may provide a comprehensive approach to symptom management by alleviating pain, improving functional mobility, and enhancing joint stability. Despite the individual benefits of these modalities, few studies have rigorously examined their combined effect in patients with PFOA. This gap in the literature underscores the need for well-designed clinical studies to evaluate whether this integrative approach yields superior outcomes compared to conventional physiotherapy alone.

This study was therefore designed to investigate the effectiveness of a combined intervention involving therapeutic ultrasound and targeted VMO strengthening exercises in patients with patellofemoral osteoarthritis. The primary objectives were to assess changes in pain intensity, functional performance, and knee joint stability following a structured 6-week intervention program. A secondary aim was to compare these outcomes with those achieved through general knee strengthening exercises without adjunct ultrasound therapy. By addressing these research questions, this study seeks to provide evidence-based guidance for the conservative management of PFOA and highlight the potential of combined modalities in optimizing patient care. The findings of this study demonstrate the effectiveness of combining therapeutic ultrasound with targeted VMO strengthening for patients with PFOA. The intervention group showed greater improvements in both pain reduction and knee function compared to the comparison group. The VMO plays a key role in medial patellar stabilization. Isolated strengthening of this muscle is supported by prior research in reducing patellofemoral joint load [10–12]. Ultrasound therapy's effects on circulation and inflammation may have further enhanced recovery and reduced symptoms [13–15]. The synergistic effect observed in the intervention group underscores the importance of combining mechanical stabilization with physiological modulation to optimize patient outcomes. Furthermore, condition-specific rehabilitation protocols—such as those focusing on biomechanical alignment and targeted muscle activation—appear to be more effective than general strengthening programs for disorders like PFOA. General exercise, although beneficial, may not adequately address the underlying biomechanical dysfunctions or neuromuscular imbalances that perpetuate symptoms in PFOA. The tailored nature of the intervention in this study likely contributed to the enhanced therapeutic outcomes observed.

These findings are consistent with emerging trends in musculoskeletal rehabilitation that favor personalized treatment strategies over standardized routines. Precision rehabilitation, informed by biomechanical assessment and patient-specific impairments, can significantly improve clinical outcomes. This study adds to a growing body of evidence advocating for integrated approaches that simultaneously address symptomatology and underlying pathology. Additionally, this research highlights the clinical utility of therapeutic ultrasound as more than a passive modality. When strategically applied in conjunction with active interventions like VMO strengthening, ultrasound can potentiate the effects of physical rehabilitation. This integrated approach may shorten recovery time, improve adherence, and increase patient satisfaction. In summary, this study supports the use of condition-specific rehabilitation protocols over general exercise prescriptions, particularly for disorders involving biomechanical misalignment and muscle imbalance. Future research should explore long-term outcomes, variations in ultrasound dosage, and the role of neuromuscular retraining to further refine conservative management strategies for PFOA.

LIMITATIONS

The study lacked randomization, which may have introduced selection bias and limited the internal validity of the findings. Additionally, the absence of a long-term follow-up restricts the ability to determine the sustainability of the observed improvements over time. The assessment of patellar tracking was based on clinical observation and subjective judgment, which may have introduced measurement bias and reduced reliability. The sample size was relatively small, limiting the generalizability of the results to broader populations with varying degrees of patellofemoral osteoarthritis. Furthermore, the study did not control for participants' baseline activity levels, which could have influenced functional outcomes. Future research should incorporate randomized controlled designs, larger sample sizes, and objective assessment tools such as dynamic MRI, real-time ultrasound imaging, or surface electromyography (EMG) to better evaluate muscular activation patterns and joint biomechanics during rehabilitation.

CONCLUSION

A 6-week program of ultrasound therapy combined with VMO-specific strengthening significantly improved pain, functional ability, and joint stability in individuals with patellofemoral osteoarthritis. These findings support the inclusion of targeted physiotherapy and adjunct modalities in the conservative management of PFOA. The results of this study highlight the importance of a multimodal approach that addresses both structural and neuromuscular impairments commonly seen in PFOA. Strengthening the vastus medialis oblique (VMO) specifically targets dynamic knee stabilization, while therapeutic ultrasound may enhance local circulation, reduce inflammation, and promote tissue healing. Together,

these interventions offer a synergistic effect, emphasizing the potential for non-invasive treatments to delay or reduce the need for pharmacological or surgical interventions. Future research should explore long-term outcomes, adherence factors, and cost-effectiveness of such integrated rehabilitation programs.

REFERENCES

1. Loyola-Sánchez A, Richardson J, MacIntyre NJ. Efficacy of ultrasound therapy for the management of knee osteoarthritis: a systematic review with meta-analysis. *Osteoarthritis Cartilage*. 2010;18(9):1117–1126.
2. Zeng C, Li H, Yang T, *et al*. Effectiveness of continuous and pulsed ultrasound for the management of knee osteoarthritis: a systematic review and network meta-analysis. *Osteoarthritis Cartilage*. 2014;22(8):1090–1099.
3. Zhang C, Xie Y, Luo X, *et al*. Effects of therapeutic ultrasound on pain, physical functions and safety outcomes in patients with knee osteoarthritis: a systematic review and meta-analysis. *Clin Rehabil*. 2016;30(10):960–971.
4. Wu Y, *et al*. Effects of therapeutic ultrasound for knee osteoarthritis: a systematic review and meta-analysis. *Clin Rehabil*. 2019;33(12):1863–1875.
5. Dantas LO, Osani MC, Bannuru RR. Therapeutic ultrasound for knee osteoarthritis: a systematic review and meta-analysis with grade quality assessment. *Braz J Phys Ther*. 2021;25(6):688–697.
6. Chen H, *et al*. Effects of low-intensity pulsed ultrasound on knee osteoarthritis: a systematic review and meta-analysis of randomized controlled trials. *Clin Rehabil*. 2022;36(9):1153–1169.
7. Zhou XY, Zhang XX, Yu GY, *et al*. Effects of low-intensity pulsed ultrasound on knee osteoarthritis: a meta-analysis of randomized clinical trials. *Biomed Res Int*. 2018;2018:7469197.
8. Jia L, Wang Y, Chen J, Chen W. Efficacy of focused low-intensity pulsed ultrasound therapy for the management of knee osteoarthritis: a randomized, double-blind, placebo-controlled trial. *Sci Rep*. 2016;6:35453.
9. Karakas A, *et al*. The effectiveness of pulsed ultrasound treatment on pain, function, synovial sac thickness and femoral cartilage thickness in patients with knee osteoarthritis: a randomized, double-blind clinical, controlled study. *Clin Rehabil*. 2020;34(12):1474–1484.
10. Kitano M, *et al*. Effects of low-intensity pulsed ultrasound on the infrapatellar fat pad in knee osteoarthritis: a randomized, double-blind, placebo-controlled trial. *J Phys Ther Sci*. 2023;35(3):163–169.
11. Yildiz SK, *et al*. The effectiveness of ultrasound treatment for the management of knee osteoarthritis: a randomized, placebo-controlled, double-blind study. *Turk J Med Sci*. 2015;45(6):1187–1191.
12. Ulus Y, *et al*. Therapeutic ultrasound versus sham ultrasound for the management of patients with knee osteoarthritis: a randomized double-blind controlled clinical study. *Int J Rheum Dis*. 2012;15(2):197–206.
13. Tascioglu F, *et al*. Short-term effectiveness of ultrasound therapy in knee osteoarthritis. *J Int Med Res*. 2010;38(4):1233–1242.
14. Huang MH, *et al*. Use of ultrasound to increase effectiveness of isokinetic exercise for knee osteoarthritis. *Arch Phys Med Rehabil*. 2005;86(8):1545–1551.
15. Sawitzke AD, *et al*. Effect of pulsed low-intensity ultrasonography on symptom relief and tibiofemoral articular cartilage thickness among veterans affairs enrollees with knee osteoarthritis: a randomized clinical trial. *JAMA Netw Open*. 2022;5(3):e220632.
16. Samaan S, Sedhom MG, Grace MO. A randomized comparative study between high-intensity laser vs low-intensity pulsed ultrasound both combined with exercises for the treatment of knee osteoarthritis. *Int J Rheum Dis*. 2022;25(8):877–886.
17. Kim ED, *et al*. Efficacy and safety of a stimulator using low-intensity pulsed ultrasound combined with transcutaneous electrical nerve stimulation in patients with painful knee osteoarthritis. *Pain Res Manag*. 2019;2019:7964897.
18. Rutjes AW, *et al*. Therapeutic ultrasound for osteoarthritis of the knee or hip. *Cochrane Database Syst Rev*. 2010;(1):CD003132.
19. Alfredo PP, *et al*. Efficacy of continuous and pulsed therapeutic ultrasound combined with exercises for knee osteoarthritis: a randomized controlled trial. *Clin Rehabil*. 2020;34(4):480–490.
20. Draper DO, *et al*. Effect of low-intensity long-duration ultrasound on the symptomatic relief of knee osteoarthritis: a randomized, placebo-controlled double-blind study. *J Orthop Surg Res*. 2018;13(1):257.
21. Mistry PR, Shukla YU. Effect of VMO Strengthening Versus Patellar Taping in Patellofemoral Pain Syndrome-A Comparative Study. *Indian J Physiother Occup Ther*. 2020;14(3):152–158.
22. Khoshkhoo MS, *et al*. Changes in VMO architecture following a physiotherapy-driven strengthening programme: a 6-week study. *Physiother Theory Pract*. 2016;32(3):211–217.
23. Elniel AR, *et al*. Comparison of closed-chain versus open-chain exercises on changes in VMO architecture. *J Orthop Sports Phys Ther*. 2017;47(4):263–269.
24. Crossley KM, *et al*. Patellofemoral pain: consensus statement from the 4th International Patellofemoral Pain Research Retreat. *Br J Sports Med*. 2016;50(14):842–850.
25. Bolgla LA, *et al*. An update for the conservative management of patellofemoral pain syndrome: a systematic review of the literature from 2000 to 2010. *Int J Sports Phys Ther*. 2011;6(2):112–125.
26. Willy RW, *et al*. Patellofemoral pain. *J Orthop Sports Phys Ther*. 2019;49(9):CPG1–CPG95.
27. Lack S, *et al*. The role of proximal muscle strength and activation in patellofemoral pain: a systematic review. *Sports Med*. 2014;44(12):1703–1713.
28. Powers CM. The influence of altered lower-extremity kinematics on patellofemoral joint dysfunction: a theoretical perspective. *J Orthop Sports Phys Ther*. 2003;33(11):639–646.
29. Barton CJ, *et al*. The efficacy of foot orthoses in the treatment of individuals with patellofemoral pain syndrome: a systematic review. *Sports Med*. 2010;40(5):377–395.
30. Collins NJ, *et al*. Physical therapies for patellofemoral pain: a systematic review and meta-analysis. *Br J Sports Med*. 2012;46(4):247–256.
31. Bennell KL, *et al*. Efficacy of physiotherapy management of knee osteoarthritis: a randomized, double-blind, placebo-controlled trial. *Ann Intern Med*. 2005;143(12):879–886.
32. Deyle GD, *et al*. Physical therapy treatment effectiveness for osteoarthritis of the knee: a randomized comparison of

supervised clinical exercise and manual therapy procedures versus a home exercise program. *Phys Ther*. 2005;85(12):1301–1317.
33. Fransen M, *et al*. Exercise for osteoarthritis of the knee: a Cochrane systematic review. *Br J Sports Med*. 2015;49(24):1554–1557.
34. Juhl C, *et al*. Impact of exercise type and dose on pain and disability in knee osteoarthritis: a systematic review and meta-regression analysis of randomized controlled trials. *Arthritis Rheumatol*. 2014;66(3):622–636.

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