Phys Med Rehab & Electrodiagnosis 2019; 1(2): 83-90
DOI: https://doi.org/10.22122/pmre.v1i2.13 **Published by** *Vesnu Publications*

Original Article

The Effect of Strengthening Exercises of the Hip Extensor and External Rotator Muscles on Patellofemoral Pain Syndrome

Received: 01 Feb. 2019
Accepted: 17 Apr. 2019
Published: 05 June 2019

Sirous Azizi[1], Morvarid Elahi[2], Afsaneh Dadarkhah[3], Elahe Shirzadi[4], Zahra Rezasoltani[5], Fateme Abdorrazaghi[4]

[1] Assistant Professor, Department of Physical Medicine and Rehabilitation, Imam Reza Hospital, AJA University of Medical Sciences, Tehran, Iran
[2] General Practitioner, Tehran University of Medical Sciences, Tehran, Iran
[3] MSc in Physical Therapy, Department of Physical Medicine and Rehabilitation, Imam Reza Hospital, AJA University of Medical Sciences, Tehran, Iran
[4] Resident, Department of Physical Medicine and Rehabilitation, Imam Reza Hospital, AJA University of Medical Sciences, Tehran, Iran
[5] Associate Professor, Department of Physical Medicine and Rehabilitation, Imam Reza Hospital, AJA University of Medical Sciences, Tehran, Iran

Keywords
Patellofemoral pain syndrome; Quadriceps muscle; Exercise therapy

Abstract

Background: Patellofemoral pain syndrome (PFPS) is one of the most common knee disorders generally causing knee pain in active youth, particularly in runners. The main symptom of this complication is a gradual-onset vague pain in the anterior region of the knee and the posterior surface of the patella. In the current study, we aimed to assess the knee pain improvement following hip extensor and external rotator muscles' strengthening exercises.

Methods: This randomized case-control clinical trial was conducted on 40 patients diagnosed with PFPS. The study group participated in the therapeutic strengthening exercise program for 8 weeks. The knee pain at rest, on running, stairs climbing, and during Scott exercise was measured at the beginning of the study and after completing the strengthening exercise.

Results: A total of 54 individuals were enrolled, out of which 14 were excluded due to insufficient patient data. The remaining 40 patients (all men) with the mean age of 26 ± 2 years were divided into two groups of 20 patients. The mean of the pain scores at the beginning of the study was 8.6 ± 0.8 and 8.2 ± 0.5 in the study group and the control group, respectively. The mean of pain scores decreased significantly to 6.0 ± 0.7 in the study group ($P < 0.01$). We had significant pain improvement on running, stairs climbing, and during Scott exercise following the strengthening exercise ($P < 0.01$).

Conclusion: Therapists can recommend this strengthening training program not only for the treatment of PFPS, but also for other knee disorders.

How to cite this article: Azizi S, Elahi M, Dadarkhah A, Shirzadi E, Rezasoltani Z, Abdorrazaghi F. **The Effect of Strengthening Exercises of the Hip Extensor and External Rotator Muscles on Patellofemoral Pain Syndrome.** Phys Med Rehab & Electrodiagnosis 2019; 1(2): 83-90.

Corresponding Author: Afsaneh Dadarkhah
Email: a.dadarkhah@ajaums.ac.ir

Introduction

Patellofemoral pain syndrome (PFPS) is one of the most common knee disorders, accounting for about 25% of all knee referrals in sports medicine and orthopedic clinics. In physiotherapy clinics, 10% of all musculoskeletal disorders (MSDs) and 20-40 percent of knee disorders are related to the PFPS.[1-6] PFPS is also referred to as anterior, chondromalacia patella, or patellofemoral knee pain.[7] This syndrome affects mostly young and active people and is often associated with overuse of the knees.[8-10] Unlike other functional disorders of the knee such as ligament injury that is associated with an acute onset, PFPS pain usually develops gradually.[11] The main symptom of this complication is a vague and diffused pain in the anterior region of the knee and the posterior surface of the patella. The main mechanism of the pain is unknown and it can be exacerbated during activities such as climbing, staggering, squatting, kneeling, and jumping.[12-14]

Although it has been described that one out of four people in the community suffers from PFPS, the incidence of PFPS has been reported between 7% and 15%, and it is more common among young people and women.[4,15-17] Six percent of patients with PFPS experience the disorder at the age of 10 to 35 years, and half of them become unable to perform certain physical activities by the age of 29.[18,19]

Although PFPS is the most common knee joint disorder, there are numerous ambiguities about the cause, pathology, and treatment of the disorder, so much so that it is referred to as the "orthopedic black hole".[12,20] The exact etiology of PFPS is unclear and may be caused by neurological, genetic, neuromuscular, or biomechanical problems in the lower extremities. This syndrome may be caused by the combination of internal and external factors.[4,21-27] There are many assumptions about the causes of the PFPS pain including muscle imbalance in quadriceps, hamstring, tensor fasciae latae (TFL), gluteus medius, vastus medialis, vastus lateralis, increased Q-angle, shortness of hamstring and quadriceps muscles, shortness and stiffness of external retinaculum, malalignment, overuse of the knee, and cartilage damage.[4,28-32] Several studies have shown reduced flexibility in quadriceps, hamstring, gastrocnemius, iliotibial band, and tensor fasciae in patients with PFPS.[7,10,14]

Many patients with PFPS respond well to the current conservative and non-surgical interventions such as physiotherapy, exercise, patellar taping, biofeedback, nonsteroidal anti-inflammatory medications, acupuncture, laser therapy, and intramuscular and articular injection.[25,33,34] Quadriceps muscles' training is the most common and the gold standard treatment of PFPS. Furthermore, studies have shown that conservative treatments may be consistent or superior to surgical treatment.[35-39] Previous studies support the effectiveness of training and stretching in the treatment of PFPS,[40-43] but the methods of strengthening the hip extensor and external rotator have not been well studied.[16,44] In the current study, we aim to assess the efficacy of strengthening on the knee pain and function in patients with PFPS.

Methods

This randomized case-control clinical trial was conducted on all the patients diagnosed with PFPS at Imam Reza Hospital, Tehran, Iran, in 2014-2015. After receiving the study approval by Institutional Review Board (IRB) at the AJA University of Medical Sciences, Tehran, and obtaining informed consent from all participants, eligible patients were assigned to either the study or the control groups. Patients' files were reviewed for pertinent demographic and clinical data and the outcomes.

Inclusion criteria: All 20 to 40 years old individuals with a 6-month history of gradual-onset pain in the anterior region of the knee and the posterior surface of the patella in at least two of the following positions were included: kneeling, squatting, running, jumping, and climbing up and down the stairs with either positive

Waldron's test[45] or positive Clarke sign.[46] None of the enrolled individuals had experienced knee trauma.

Exclusion criteria: All individuals with history of knee trauma including patella dislocation, ligament laceration, meniscus and joint capsule damage, history of lumbar disc herniation, lower extremities surgeries, any musculoskeletal discomfort causing dizziness and presenting sustained swollen knee during the past year, and any pain in the hip and ankles were excluded from the clinical trial.

All eligible individuals were entered the study up to one week after measuring weight, height, and pain severity at the first measurement session. The secondary measurement (post-test) was performed up to one week after the completion of the therapeutic exercises. The second measurement session was similar to the initial measurement session. All exercise techniques were based on Therapeutic Exercise: Foundations and Techniques by Kisner and Colby.[47]

The study group participated in the therapeutic strengthening exercise program which involved exercises to strengthen the hip extensor and external rotator muscles for 8 weeks (twice a day, 3 sessions per week, every other day to allow time for recovery). The training sessions were supervised by a trainer to ensure that the individuals performed the exercises correctly. The participants in the training group attended at least 22 out of the 24 training sessions and could not be absent in two consecutive training sessions, otherwise they would be excluded from the study process. It should be noted that the control group, beside daily activities, was not allowed to perform any specific lower extremities' training during the 8 weeks. Meanwhile, patients in both groups were asked to not take any analgesics to reduce knee pain during the study.

To assess the pain improvement, Visual Analogue Scale (VAS) forms were completed at the two measurement sessions. The standard scale form developed by Grabiner et al.[48] in 1994, was applied to measure the functional knee disability. This questionnaire is specifically designed for patients with patellofemoral articular disorders to assess the cognitive influences on the perception of pain and functional knee restrictions in relation to the patellofemoral joint disorder during daily activities. The questionnaire has 13 questions, with a total score of 100. A score of 100 indicates maximum knee efficiency and a score of 0 indicates maximum disability. Validity of this questionnaire has been confirmed and its reliability is 96%.[48]

Data analysis was completed using SPSS software (version 20, IBM Corporation, Armonk, NY, USA). For each measured variable, descriptive values were expressed as the mean and standard deviation (SD). Analysis of quantitative variables was performed using t-test, paired t-test, Kolmogorov–Smirnov test (K-S test), and analysis of covariance (ANCOVA). Categorical variables were compared using the chi-square test. Reported P-values were 2-tailed and $P < 0.05$ was considered statistically significant.

Results

A total of 54 individuals were enrolled, out of which 14 were excluded due to insufficient patient data. The remaining 40 patients (all men) with the mean age of 26 ± 2 years and other basic demographic data were divided into 2 groups of 20 men (Table 1).

Table 1. Demographic characteristics of the study and control groups, before and following the strengthening exercises

Variables	Study group		Control group		P
	Beginning of the study	Week 8	Beginning of the study	Week 8	
Age (year) (mean ± SD)	26.0 ± 3.0		29.0 ± 2.0		0.11
Height (cm) (mean ± SD)	169.0 ± 5.0		171.0 ± 4.0		0.84
Weight (kg) (mean ± SD)	70.0 ± 3.0	72.0 ± 2.0	71.0 ± 3.0	70.0 ± 8.0	0.91
Duration of disease (month) (mean ± SD)	6.2 ± 2.3		5.6 ± 3.1		0.54

SD: Standard deviation

Table 2. Comparison of the mean scores of the knee pain and functions in both study and control groups, before and following strengthening exercises

Variables	Study group		Control group		P
	Beginning of the study (Mean ± SD)	Week 8 (Mean ± SD)	Beginning of the study (Mean ± SD)	Week 8 (Mean ± SD)	
Knee pain at rest	8.6 ± 0.8	6.0 ± 0.7	8.2 ± 0.5	8.0 ± 0.6	< 0.01
Knee function over running	59.0 ± 9.0	82.0 ± 12.0	64.0 ± 5.0	65.0 ± 3.0	< 0.01
Knee function over Scott exercise	61.0 ± 7.0	86.0 ± 8.0	59.0 ± 8.0	57.0 ± 6.0	< 0.01
Knee function over stair climbing	55.0 ± 8.0	84.0 ± 9.0	58.0 ± 10.0	62.0 ± 8.0	< 0.01

SD: Standard deviation

The mean of the pain scores at the beginning of the study was 8.6 ± 0.8 and 8.2 ± 0.5 in the study and the control groups, respectively. Scores decreased to 6.0 ± 0.7 in the study group, while there was no change in the control group (P < 0.01) (Table 2) (Figure 1).

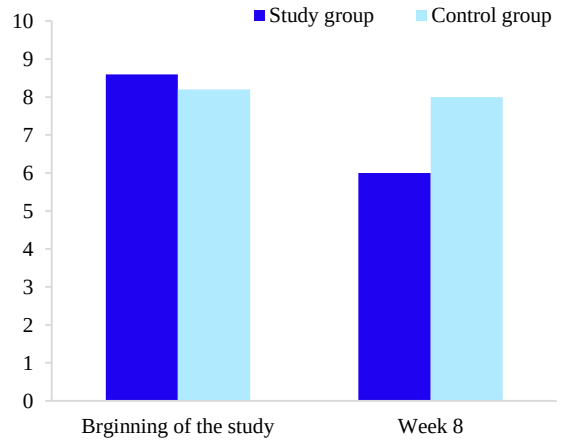

Figure 1. Comparison of the mean scores of knee pain at rest before and after strengthening exercises in the study and control groups

There was a significant pain improvement on running, stairs climbing, and during Scott exercise after 8 weeks of strengthening exercises for hip extensor and external rotator muscles (P < 0.01) (Table 2).

The mean of the pain scores on running at the beginning of the study was 59 ± 9 and 64 ± 5 in the study and the control groups, respectively. The knee function over running improved to 82 ± 12 in the study group, while there was no change in the control group (P < 0.01) (Table 2) (Figure 2).

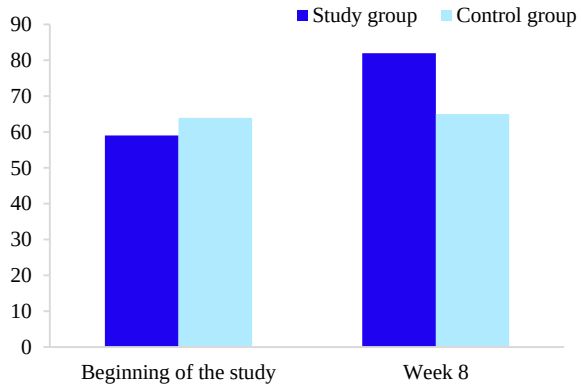

Figure 2. Comparison of the mean scores of knee pain on running before and after strengthening exercises in the study and control groups

The mean of the pain scores on stairs climbing at the beginning of the study was 55 ± 8 and 58 ± 10 in the study and the control groups, respectively. The knee function over Scott exercise improved to 84 ± 9 in the study group, while there was no significant change in the control group (P < 0.01) (Table 2) (Figure 3).

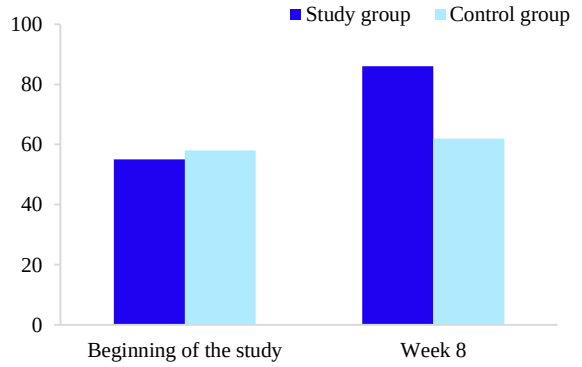

Figure 3. Comparison of the mean scores of knee pain on stair climbing before and after strengthening exercises in the study and control groups

The mean of the pain scores during Scott exercise at the beginning of the study was 61 ± 7 and 59 ± 8 in the study and the control groups, respectively. The knee function over Scott exercise improved to 86 ± 8 in the study group, while there was no significant change in the control group ($P < 0.01$) (Table 2) (Figure 4).

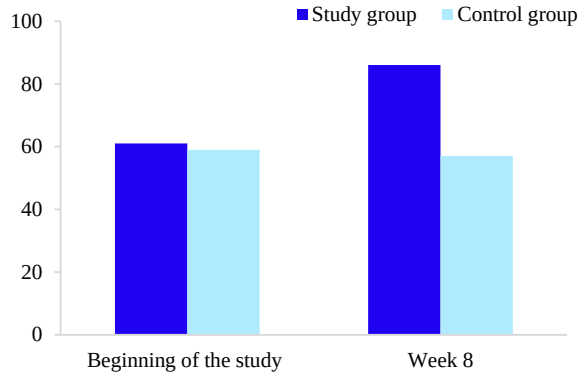

Figure 4. Comparison of the mean scores of knee pain during Scott exercise before and after strengthening exercises in the study and control groups

Discussion

PFPS is one of the most common knee complaints. Imposing great medical expenses, this syndrome can have a negative effect on daily or athletic activities and lead to absence from workplace if not treated properly.

In general, failure in diagnosis and timely treatment of PFPS may lead an individual to seek invasive options like surgery,[32] in that case postoperative complications may lead to further movement limitations. Early conservative treatments should be the basis for PFPS treatment to prevent the abovementioned problems.

According to previous studies, two different methods of strengthening quadriceps muscles have been demonstrated: therapeutic exercises and electrical stimulation. Although both treatment methods reduce pain and improve the knee function, therapeutic exercises are usually preferred to electrical stimulation as therapeutic exercise can increase the range of motions in the knee, which is not observed in the quadriceps amplification by electrical stimulation.[7] Our results demonstrated that hip extensor and external rotator muscles' strengthening exercises had a significant effect on pain improvement in patients suffering from PFPS as well ($P < 0.01$). These results are consistent with the previous studies.[42,49]

The muscles involved in the movements of external hip rotators are the piriformis, superior gemellus, inferior gemellus, obturator internus, obturator externus, and quadratus femoris. The muscles involved in hip joint extension movements are gluteus maximus, adductor magnus (hamstring portion), biceps femoris, semimembranosus, and semitendinosus. Bolgla et al. in 2008 reported that hip external rotators in women treated with physiotherapy were 30% weaker compared to a control group.[50] Moreover, Ireland et al. in 2003 reported that the isometric strengthening exercises of the abductor and external rotator muscles in a group with post-traumatic stress disorder (PTSD) were 26% and 36% lower than a healthy group.[44] Other previous studies confirmed the improvement of quadriceps muscle and daily activity functions after therapeutic exercises such as isokinetic, static, eccentric, and isometric training.[42,51,52] In the current study, we assessed the effect of strengthening exercises of the hip extensor and external rotator muscles on the pain and function improvement in patients with PFPS.

The Q-angle formed by the vector for the combined pull of the quadriceps femoris muscle and the patellar tendon, is important because of the lateral pull it exerts on the patella. Heegaard et al. observed that an increased Q-angle and knee flexion could increase the amount of contact force in the external compartment of the patellofemoral joint.[53] Besier et al. reported that the contact force was higher on the lateral surface of the knee compared to the inner side by measuring the rate of patellofemoral joint contact force during Scott's activity at 0 to 60 degrees.[54] In the current study, we assessed the effect of strengthening exercises

of the hip extensor and external rotator muscles on the pain during Scott's activity. The results showed that Scott activity scores before and after the strengthening exercises were significantly different ($P < 0.01$).

Leetun et al. examined gender differences in relation to central muscle strength and lower extremity disorders in 60 male and 79 female athletes. They found that women showed significantly weaker hip extensor and external rotator muscles, leading to lower extremities and wrist disorders. Women also showed less endurance in the trunk muscles compared to men.[55] Overall, there are fewer studies on the PFPS in men and most studies have been conducted on women.[56] In the current study, all individuals were men and our results confirm that the strengthening exercises can be recommended for all patients as a preventive method, particularly in soldiers and military personnel.

Conclusion

Considering the strengthening trainings that have been applied to reduce the pain of PFPS in other studies, the movements used in this study are simpler and more practical. We concluded that using this method along with other therapeutic methods could increase the effectiveness of other therapies such as medication. In addition, therapists can recommend this strengthening training program not only for the treatment of PFPS, but also for other knee disorders

Acknowledgments

We would like to show our gratitude to all patients for cooperating with us during the course of this research.

Conflict of Interest

Authors have no conflict of interest.

References

1. Cutbill JW, Ladly KO, Bray RC, Thorne P, Verhoef M. Anterior knee pain: A review. Clin J Sport Med 1997; 7(1): 40-5.
2. Kannus P, Aho H, Jarvinen M, Niittymaki S. Computerized recording of visits to an outpatient sports clinic. Am J Sports Med 1987; 15(1): 79-85.
3. Sanchis-Alfonso V. Anterior knee pain and patellar instability. 1st ed. London, UK: Springer-Verlag; 2006.
4. Earl JE, Vetter CS. Patellofemoral pain. Phys Med Rehabil Clin N Am 2007; 18(3): 439-58, viii.
5. Khademi-Kalantari K, Mahmoodi AS, Akbarzadeh BA, Rezayi M, Rahimi A, Naimee S. Effects of non-surgical joint distraction in the treatment of severe knee osteoarthritis. J Bodyw Mov Ther 2014; 18(4): 533-9.
6. Dastmenash S, Van den Tillaar R, Jacobs P, Shafiee GH, Shojaedin SS. The effect of whole body vibration, pnf training or a combination of both on hamstrings range of motion. World Appl Sci J 2010; 11(6): 744-51.
7. Mascal CL, Landel R, Powers C. Management of patellofemoral pain targeting hip, pelvis, and trunk muscle function: 2 case reports. J Orthop Sports Phys Ther 2003; 33(11): 647-60.
8. Stuart MJ, Meglan DA, Lutz GE, Growney ES, An KN. Comparison of intersegmental tibiofemoral joint forces and muscle activity during various closed kinetic chain exercises. Am J Sports Med 1996; 24(6): 792-9.
9. Minoonejad H, Rajabi R, Ebrahimi-Takamjani E, Alizadeh MH, Jamshidi AA, Azhari A, et al. Combined open and closed kinetic chain exercises for patellofemoral pain syndrome: A randomized controlled trial. World J Sport Sci 2012; 6(3): 278-85.
10. Smith AD, Stroud L, McQueen C. Flexibility and anterior knee pain in adolescent elite figure skaters. J Pediatr Orthop 1991; 11(1): 77-82.
11. Rubin BD, Collins HR. Runner's knee. Physician Sportsmed 1980; 8(6): 47-58.
12. Green ST. Patellofemoral syndrome. J Bodyw Mov Ther 2005; 9(1): 16-26.
13. Leardini A, Stagni R, O'Connor JJ. Mobility of the subtalar joint in the intact ankle complex. J Biomech 2001; 34(6): 805-9.
14. Brody LT, Thein JM. Nonoperative treatment for patellofemoral pain. J Orthop Sports Phys Ther 1998; 28(5): 336-44.
15. Mohammadi E, Rajabi R, Alizadeh MH. Comparison of the torso stabilizer muscles endurance infemale athletes with and without patellofemoral pain syndrome. World J Sport Sci 2012; 7(3): 149-53.
16. Akuthota V, Ferreiro A, Moore T, Fredericson M. Core stability exercise principles. Curr Sports Med Rep 2008; 7(1): 39-44.
17. Brechter JH, Powers CM. Patellofemoral joint stress during stair ascent and descent in persons with and without patellofemoral pain. Gait Posture 2002; 16(2): 115-23.

18. Blond L, Hansen L. Patellofemoral pain syndrome in athletes: A 5.7-year retrospective follow-up study of 250 athletes. Acta Orthop Belg 1998; 64(4): 393-400.

19. Ng GY, Zhang AQ, Li CK. Biofeedback exercise improved the EMG activity ratio of the medial and lateral vasti muscles in subjects with patellofemoral pain syndrome. J Electromyogr Kinesiol 2008; 18(1): 128-33.

20. Dye SF. The pathophysiology of patellofemoral pain: A tissue homeostasis perspective. Clin Orthop Relat Res 2005; (436): 100-10.

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

22. Draper CE, Besier TF, Gold GE, Fredericson M, Fiene A, Beaupre GS, et al. Is cartilage thickness different in young subjects with and without patellofemoral pain? Osteoarthritis Cartilage 2006; 14(9): 931-7.

23. Powers CM. The influence of altered lower-extremity kinematics on patellofemoral joint dysfunction: a theoretical perspective. J Orthop Sports Phys Ther 2003; 33(11): 639-46.

24. Dixit S, DiFiori JP, Burton M, Mines B. Management of patellofemoral pain syndrome. Am Fam Physician 2007; 75(2): 194-202.

25. LaBella C. Patellofemoral pain syndrome: Evaluation and treatment. Prim Care 2004; 31(4): 977-1003.

26. Sanchis-Alfonso V, Rosello-Sastre E. Anterior knee pain in the young patient--what causes the pain? "Neural model". Acta Orthop Scand 2003; 74(6): 697-703.

27. Rodeo SA. Knee pain in competitive swimming. Clin Sports Med 1999; 18(2): 379-87, viii.

28. Martens M, Wouters P, Burssens A, Mulier JC. Patellar tendinitis: Pathology and results of treatment. Acta Orthop Scand 1982; 53(3): 445-50.

29. Grelsamer RP. Patellar malalignment. J Bone Joint Surg Am 2000; 82(11): 1639-50.

30. Cowan SM, Crossley KM. Does gender influence neuromotor control of the knee and hip? J Electromyogr Kinesiol 2009; 19(2): 276-82.

31. Boling MC, Bolgla LA, Mattacola CG, Uhl TL, Hosey RG. Outcomes of a weight-bearing rehabilitation program for patients diagnosed with patellofemoral pain syndrome. Arch Phys Med Rehabil 2006; 87(11): 1428-35.

32. Piva SR, Goodnite EA, Childs JD. Strength around the hip and flexibility of soft tissues in individuals with and without patellofemoral pain syndrome. J Orthop Sports Phys Ther 2005; 35(12): 793-801.

33. Nouri F, Raeissadat SA, Eliaspour D, Rayegani SM, Rahimi MS, Movahedi B. Efficacy of high-power laser in alleviating pain and improving function of patients with patellofemoral pain syndrome: A single-blind randomized controlled trial. J Lasers Med Sci 2018; 10(1): 37-43.

34. Bizzini M, Childs JD, Piva SR, Delitto A. Systematic review of the quality of randomized controlled trials for patellofemoral pain syndrome. J Orthop Sports Phys Ther 2003; 33(1): 4-20.

35. Kettunen JA, Harilainen A, Sandelin J, Schlenzka D, Hietaniemi K, Seitsalo S, et al. Knee arthroscopy and exercise versus exercise only for chronic patellofemoral pain syndrome: A randomized controlled trial. BMC Med 2007; 5: 38.

36. Fagan V, Delahunt E. Patellofemoral pain syndrome: a review on the associated neuromuscular deficits and current treatment options. Br J Sports Med 2008; 42(10): 789-95.

37. Bolgla LA, Boling MC. 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): 112-25.

38. Fredericson M, Powers CM. Practical management of patellofemoral pain. Clin J Sport Med 2002; 12(1): 36-8.

39. 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(2): 122-30.

40. Natri A, Kannus P, Jarvinen M. Which factors predict the long-term outcome in chronic patellofemoral pain syndrome? A 7-yr prospective follow-up study. Med Sci Sports Exerc 1998; 30(11): 1572-7.

41. Barton CJ, Webster KE, Menz HB. Evaluation of the scope and quality of systematic reviews on nonpharmacological conservative treatment for patellofemoral pain syndrome. J Orthop Sports Phys Ther 2008; 38(9): 529-41.

42. 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.

43. Crossley K, Bennell K, Green S, Cowan S, McConnell J. Physical therapy for patellofemoral pain: A randomized, double-blinded, placebo-controlled trial. Am J Sports Med 2002; 30(6): 857-65.

44. Ireland ML, Willson JD, Ballantyne BT, Davis IM. Hip strength in females with and without patellofemoral pain. J Orthop Sports Phys Ther 2003; 33(11): 671-6.

45. Nijs J, Van GC, Van der auwera C, Van de V. Diagnostic value of five clinical tests in patellofemoral pain syndrome. Man Ther 2006; 11(1): 69-77.

46. Tyler TF, Nicholas SJ, Mullaney MJ, McHugh MP. The role of hip muscle function in the treatment of patellofemoral pain syndrome. Am J Sports Med

2006; 34(4): 630-6.
47. Kisner C, Colby LA. The hip. In: Kisner C, Colby LA, editors. Therapeutic exercise: Foundations and techniques. Philadelphia, PA: F.A. Davis; 1996. p. 709-63.
48. Grabiner MD, Koh TJ, Draganich LF. Neuromechanics of the patellofemoral joint. Med Sci Sports Exerc 1994; 26(1): 10-21.
49. Akbari A, Hosseinifar M, Kheirabadi N, Jahanshahi Javaran P. Comparison of the effect of exercise therapy with transcutaneous electrical nerve stimulation on improvement of pain and function in patients with patellofemoral pain syndrome. Armaghane-danesh 2008; 13(1): 15-27. [In Persian].
50. Bolgla LA, Malone TR, Umberger BR, Uhl TL. Hip strength and hip and knee kinematics during stair descent in females with and without patellofemoral pain syndrome. J Orthop Sports Phys Ther 2008; 38(1): 12-8.
51. McMullen W, Roncarati A, Koval P. Static and isokinetic treatments of chondromalacia patella: a comparative investigation. J Orthop Sports Phys Ther 1990; 12(6): 256-66.
52. Thomee R. A comprehensive treatment approach for patellofemoral pain syndrome in young women. Phys Ther 1997; 77(12): 1690-703.
53. Heegaard J, Leyvraz PF, Curnier A, Rakotomanana L, Huiskes R. The biomechanics of the human patella during passive knee flexion. J Biomech 1995; 28(11): 1265-79.
54. Besier TF, Draper CE, Gold GE, Beaupre GS, Delp SL. Patellofemoral joint contact area increases with knee flexion and weight-bearing. J Orthop Res 2005; 23(2): 345-50.
55. Leetun DT, Ireland ML, Willson JD, Ballantyne BT, Davis IM. Core stability measures as risk factors for lower extremity injury in athletes. Med Sci Sports Exerc 2004; 36(6): 926-34.
56. Jacobs CA, Uhl TL, Mattacola CG, Shapiro R, Rayens WS. Hip abductor function and lower extremity landing kinematics: Sex differences. J Athl Train 2007; 42(1): 76-83.