Original Article

Restorative effects of exercise rehabilitation and bracing on females with lateral displacement of patella

Atiye Karimzadehfini, Vahid Zolaktaf, Babak Vahdatpour[1]

Department of Sports, Injuries and Corrective Exercises, Faculty of Physical Education and Sport Sciences, University of Isfahan, [1]Department of Physical Medicine and Rehabilitation, Isfahan University of Medical Sciences, Isfahan, Iran

Abstract

Background: This investigation compared the effects of exercise rehabilitation and bracing on muscle flexibility and strength as well as knee proprioception and pain in female sufferers of lateral displacement of patella (LDP).

Materials and Methods: Twenty-two females with unilateral LDP were randomly divided into two groups to receive exercises ($n = 12$) or patellar brace ($n = 10$). Both groups were evaluated before and after 8 weeks with isokinetic dynamometer (Biodex System 3 Pro) for muscle strength and proprioception, with SLR, Active Knee Flexion, and Sit and Reach tests for flexibility assessment and with a visual analog scale for pain.

Results: Muscle flexibility in both exercise and bracing groups improved ($F_{(1,20)} \geq 5.99$ and $P \leq 0.024$), whereas improvement in bracing group was not significant. Significant interaction was observed in favor of exercise group in 2 strength tests of knee flexion and knee extension ($F_{(1,20)} \geq 6.564$ and $P \leq 0.019$). For proprioception, a significant interaction was observed in favor of bracing group ($F_{(1,20)} = 7.944$ and $P = 0.011$). Also the results showed both exercise rehab and brace decreased significantly pain severity during stair ascending and descending.

Conclusion: These results suggest that better flexibility and more strength in exercise group somehow reduced the stress on patellofemoral joint and it, in turn, alleviated the symptoms and pain. It is also likely that relieving effects of brace and improvement of proprioception by it allows patients to be more physically active and it could have, more or less, effects similar to exercise. Therefore both exercise and brace could be prescribed for patients with LDP. It seems application of the patellar brace combined with exercise might be a better treatment for these patients, because they could improve strength, flexibility and proprioception.

Key Words: Exercise rehabilitation, lateral displacement of patella, patellar bracing

Address for correspondence:
Dr. Babak Vahdatpour, Department of Physical Medicine and Rehabilitation, Isfahan University of Medical Sciences, Isfahan, Iran.
E-mail: vahdatpour@med.mui.ac.ir
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INTRODUCTION

Lateral displacement of the patella (LDP) is defined as one of the main causes of symptomatic patellofemoral joints.[1] About 50% of patients with patellofemoral pain are diagnosed with malalignment of patella. It is typically characterized by excessive lateral translation of the patella relative to the femur and occurs near

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full knee extension.[2,3] This incongruent position of the patella can be a major component of patellar pain in adults.[4-6]

Joint laxity and muscular imbalance are suggested as two main causative factors of LDP. It is suggested that muscular imbalance originates from muscular tightness and/or weakness. Some researchers proposed that the main cause originates from tightness of muscles surrounding the knee joint (especially quadriceps and/or hamstrings) and tight lateral structures.[7-9] Some others believe that weakness of vastus medialis oblique is the main cause, as pain gets more sever at the later stages of knee extension.[10-12]

Non-treated LDP could prove itself in forms of patellar subluxation or dislocation, chondromalacia, osteoarthritis, and/or joint deformity.[13,14] LDP may also lead to damage in joint capsule and surrounding soft tissues. From a kinesiologic perspective, the aforementioned damages individually or combatively may cause misperception of proprioceptive input from these structures.[15] Therefore, one of the main problems of these patients is also reduction of proprioception.

A variety of invasive and conservative treatment protocols has been applied to manage patients with LDP. In general, conservative treatment regimens include exercise rehabilitation, bracing, taping, or a combination of them. There is a considerable literature that supports the use of them for treatment of LDP.[1,8,16] But, a question remains, which treatment is more advantageous. Patellar taping as part of conservative treatment for LDP is readily used by physiotherapists. Although the exact mechanism for its success remains unknown, investigators have believed that this technique could adjust patellar position, enhance contraction of the vastus medialis oblique muscle, and hence, reduce pain.[17] We excluded taping from our study, because many patients cannot accomplish an appropriate taping by themselves, nor they can readily find professional assistance for this service every day. Alternatively we preferred the use of bracing of knee which is firstly inexpensive and affordable and secondly needs a little instruction and practice. Patients often report benefits from wearing braces although these benefits need to be confirmed by investigation. Primary function of them is increasing warmth, providing compression and feeling of support to the knee. Consequently, they may limit patella movement and enhance proprioception and hence decrease pain.[18] Bracing has an important advantage to exercise rehab as well. It is less time consuming and effort demanding. Nevertheless, some people still fancy exercise rehab for treatment, as they think exercise is fun and produces some extra benefits such as muscular fitness. This study compares the effects of exercise rehab and Palumbo patellar brace on muscle flexibility and strength as well as knee proprioception and pain in patients with LDP. It reserves surgical interventions for more severe or difficult cases.[1,19]

MATERIALS AND METHODS

This quasi-experimental study followed a randomized and repeated measures design. Twenty-two female patients between 18 to 35 years of age were recruited from physical medicine and rehabilitation clinics (Isfahan Ayatollah Kashani medical center and Al Zahra Hospital). Each patient was selected for inclusion in the study based on the presence of the hallmark signs and symptoms of lateral displacement of patella, as assessed by an experienced physical medicine specialized then the Merchant's X-ray view of the patellofemoral joint. Since the primary goal of this study was to compare the effects of bracing and exercise rehab on the LDP only patients with this type of abnormal patellar alignment were included in this investigation while patients with a history of patellofemoral dislocation and/or subluxation, patellofemoral osteoarthritis, bone abnormality, and surgery of meniscus and ligament history were excluded. Pre-treatment age, height, weight, body mass index (BMI), and pain duration of patients was recorded [Table 1].

Patients were divided into two groups by method of random selection. Prior to participation; all subjects were informed of the nature of the study and gave their written consent to participate. An institutional review board approved all procedures before testing.

Radiographic evaluation

To determine the patients suffering LDP, Merchant's X-ray view was taken. The Merchant's view of the

Table 1: Initial characteristics of two groups

Characteristic	Group	Mid	Mean±SD	*F* (Sig)
Age (year)	Exercise	23	24.2±5.44	1.08 (0.31)
	Brace	28	26.7±5.53	
	Total	24	25.3±5.49	
Height (cm)	Exercise	161.5	161.6±4.16	0.09 (0.76)
	Brace	159.0	162.7±11.10	
	Total	160.5	162.1±7.88	
Body weight (kg)	Exercise	60.5	61.8±12.55	0.004 (0.95)
	Brace	60.0	61.5±12.36	
	Total	60.5	61.6±12.17	
Body mass index (kg/m^2)	Exercise	22.6	23.7±5.44	0.14 (0.70)
	Brace	23.5	23.0±2.66	
	Total	23.4	23.4±4.32	
Pain duration (month)	Exercise	15	14.2±6.66	7.56 (0.01)
	Brace	30	31.5±20.55	
	Total	18	22.0±16.78	

patella provides valuable information concerning the location of the patella within the trochlear grove.[20] For the Merchant's view, the knee is flexed 45°over the end of the table and the x-ray beam is inclined 30° downward [Figure 1a]. LDP is assessed by measuring the congruence angle, which reflects the relationship of the patellar articular ridge to the intercondylar sulcus and averages approximately 6°±11° in the medial direction [Figure 1b].[16] (LDP is happened when congruence angle is in the lateral direction). The sulcus angle is formed by the highest points of the medial and lateral femoral condyles and the lowest point of the intercondylar sulcus and is approximately 138° ± 6°. A sulcus angle of >145° is indicative of trochlear dysplasia.[21] This view is used as well as to assess for patellar tilt, patellar subluxation, and trochlear dysplasia.

The patients of bracing group (n = 10) did not participate in exercise but were instructed to wear the Palumbo patellar brace [Figure 2] on the suffered knee during daily activities for 8 weeks. This specially designed brace consists of a neoprene knee cuff with an opening for the patella, a C-shaped buttress, and two movable straps used to maintain the brace in a properly fixed position.[18] The appropriate size of this brace was selected for each patient. The brace was applied with the patient seated with the affected knee relaxed in a fully extended position to permit "free" movement of the patella. The cuff was placed securely around the patellofemoral joint and fastened above and below the joint via straps. Care was taken to ensure the patella was centrally located in the opening. The patella was palpated, and the C-shaped buttress that was placed in the lateral side of the patella, pushed the patella medially while the straps were applied, pulled firmly, and attached to the medial side of the brace. This created a laterally force acting on the laterally displaced patella.[6,18]

Patients of exercise group were given an 8-week exercise program (five sessions in per week i.e., two sessions in clinic under the supervision of the same therapist and three sessions in home). Per session was 30 minutes and included three parts: (1) Warm up (2) Special exercise for treating LDP (3) Cold down. Special exercise included strengthening and stretching exercise.[10] After every 2 weeks, intensity of exercises increased. This exercise program was not fixed for all the patients. It means if one patient during the period of exercise was feeling pain, therapist decreased times and repetitions of her exercise.

Same evaluations were repeated in both groups prior to the treatment, and at the end of the 8 weeks treatment period [Table 2].

To measure pain, we used visual analogue scale (VAS). During VAS evaluation, patients were asked to score their pain severity that experienced during stair-climbing and descending on a 10 cm horizontal line with a scale between 0 and 10 (0: no pain, 10: maximum, unbearable pain).[22]

Table 2: Assessment results of the groups

Test	Pre-treatment Mean±SD		Post-treatment Mean±SD		
	Group I*	Group II**	Group I	Group II	
Pain (0-10)	6.5±0.3	6.5±0.4	2.5±0.3	3.0±0.6	F=0.97 P=0.337
Sit and rich (cm)	30.5±2.2	28.8±2.4	38.8±2.2	31.9±2.3	F=6.08 P=0.023
SLR (degree)	58.5±2.0	60.4±1.6	61.2±2.7	62.7±1.6	F=0.01 P=0.923
Active knee flex (degree)	124±3.0	122±4.4	135±2.0	128±4.3	F=6.18 P=0.022
Strength of knee ext (N/m)	30.2±5.0	38.4±7.9	43.2±5.1	39.5±7.2	F= 13.5 P=0.002
Strength of knee flex (N/m)	37.6±5.5	33.9±4.6	45.8±5.3	32.1±5.3	F=6.60 P=0.019
Proprioception error (degree)	3.9±0.7	7.1±1.4	3.2±0.5	3.2±0.8	F=7.944 P=0.011

*Group I: Exercise rehab **Group II: Patellar bracing

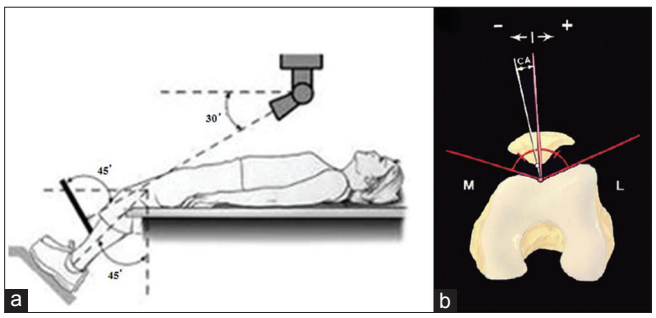

Figure 1: (a) Merchant's X-ray view. (b) Patellofemoral congruence angle

Figure 2: Palumbo patellar brace

To evaluation flexibility, we used Sit and Reach, Active Knee Flexion, and SLR tests.

To measurement strength of quadriceps and hamstring muscles, we administered knee flexion and extension isometric tests by an isokinetic dynamometer (Biodex System 3 Pro) that has a high validity to measurement strength.[23,24] In this test, the subject was seated on the dynamometer chair with the back angle of 85° from the horizontal. With using the straps on the chair, the subject was kept firmly on the chair and her knee was flexed to 45°. The subject was instructed to exert as much force as possible using an isometric contraction while extending then flexing the knee against the force-sensing arm of the dynamometer. The contraction was repeated for three trials and the trial with the maximum value was recorded.[24]

Assessment through isokinetic machines is one of the best methods for determining proprioception error of joints because of their high validity.[25] So to measure knee proprioception error, we assessed the precision of reproduction of knee angle by an isokinetic dynamometer (Biodex System 3 Pro). Dynamometer was adjusted in the stable angle of 90° and the seatback tilted set at 70°-85° so that the person feels comfortable.[26] During testing to assess proprioception error, straps were used to fix thigh and upper body of subject. The range of knee movement was selected from 45° to 90° of knee flexion.[27] Proprioception test performed unilaterally (on suffered knee) by active mode in one angle; 45°.[28] After set anatomical reference, knee joint was placed in starting angle (90°). To memorize target angle, subjects were passively moved leg to the target angle (45°), hold knee at target angle for 5 seconds, and returned to starting position (90°). Then, knee joint was actively moved toward target angle. The subject was instructed to press the stop button when the memorized angle was recreated while her eyes are closed. The test was repeated for three trials and the absolute difference between the perceived angle and the target angle was calculated for each trial and the trial with the minimum value was recorded. A quiet place was selected for this test.

In this paper, descriptive statistics to represent and characterize data and inferential statistics for data analysis were used. In the descriptive statistics mean and standard deviations were used as indicators of central tendency and dispersion measurements, respectively and in inferential statistics Using SPSS 16, data was analyzed by "repeated measures ANOVA".

RESULTS

Every patient included in this study had Lateral Displacement of the Patella and demonstrated by an experienced physical medicine specialized. When the physical characteristics and pain durations of both groups were compared, no statistically significant difference was found between the two groups in terms of the mean weight values, age, height and BMI, while a statistically significant difference was observed between the mean pain duration values of patients.

In assessment of pain although a statistically significant reduction was found in the pre-treatment – post-treatment severity of pain during stair ascending and descending in both groups but there was no significant interactions between groups ($F_{(2,20)}$ = 0.97 and P = 0.337). This means that both groups had relatively similar conditions in the pre-treatment and post-treatment and result in had the same improvement.

Total results: Both exercise rehab and brace decreased significantly pain intensity during stair ascending and descending.

There were significant interactions between groups in terms of Sit and Reach ($F_{(2,20)}$= 6.08, P = 0.023) and Active Knee Flexion ($F_{(2,20)}$ = 6.18 and P = 0.022) in favor of exercise rehab group. No significant interaction was found between the groups in terms of SLR test ($F_{(2,20)}$ = 0.01 and P = 0.923). Total results: Exercise rehab increased flexibility more than wearing the brace.

When evaluating strength of flexor and extensor muscles of knee, significant interactions in favor of exercise rehab group ($F_{(1,20)}$≥6.564 and $P \leq 0.019$) were observed. The amount of strength of flexor muscles increased 8/14 N-m in exercise group while amount this factor decreased 1/84 N-m for bracing group. Total results: Exercise rehab increased muscle strength more than wearing the brace.

For proprioception, a significant interactions was observed in favor of bracing group ($F_{(2,20)}$=7.944 and P = 0.011). Total results: Wearing the brace increased proprioceptive ability more than exercise rehab.

DISCUSSION

The aim of this study was to compare the effectiveness of exercise rehabilitation and bracing on strength and flexibility of muscles as well as proprioception and pain severity in female sufferers of LDP. No difference was found between the demographic characteristics of two

groups. Therefore, it was considered that the treatment result was not affected by demographic characteristics. The results showed that exercise program significantly improved muscle flexibility while no significant improvement observed in bracing group. Flexibility restrictions of soft tissues around the knee joint are the risk factors affecting on lateral displacement of the patella. In this study, stretching exercises focused on quadriceps, hamstring, and tight lateral structures. Quadriceps is one of the muscles structures that is directly affecting on patella alignment during functional activities. Flexibility restriction of this muscle causes muscular imbalance and the result in Patella is out of its normal alignment. Another muscle affecting on the lateral displacement of patella is hamstring. Decreased flexibility in the hamstrings can increase the demand on the quadriceps during extension of the knee and increased joint forces at the patella-femoral joint.[24] Tight lateral structures contribute to a lateral patella pull and result in patella displacement. Tightness in any or all of the above structures can increase stress on patellofemoral joint or alter joint mechanics contributing to an increased risk of experiencing LDP as well as pain. We conclude that stretching exercises can increase flexibility of these shorten structures and result in decrease the pain in these patients. Also it seems the reason of improvement in bracing group is reduction the stress on patellofemoral joint. Although there are no available studies in literature comparing the effects of exercise program and bracing on flexibility of muscles in sufferers LDP, it was demonstrated in some studies relationship between shortening of these muscles and PFPS. Dewhurst *P* after a 3-week static stretching program, observed Increasing flexibility of quadriceps and improvement the performance of patellofemoral joint.[29] Smith *et al*., reported patellofemoral pain syndrome in young Skaters was related to decreasing in hamstring flexibility.[30] Piva *et al*., recorded hamstring length in patients with patellofemoral pain syndrome was significantly shorter than the control group.[31] Interestingly, this contrasts with the findings of Witvrouw *et al*., who observed no statistically significant difference in hamstring length between participants who developed PFPS and those who did not.[32] Our results are in line with Piva and Smith *et al*. studies. In the study by Witvrouw *et al*., the group was younger (aged 17-21 years) than in the current study (18-35 years), so direct comparisons cannot be drawn.

We also observed significant increasing in strength of knee extensor and flexor muscles in exercise group while in bracing group strength improvement of knee extensor muscles was not significant as well as strength of knee flexor muscles decreased. The patella articulates with patellofemoral groove in the femur. Several muscles act on the patella to provide stability and keep it tracking properly. Weakness in each of these muscles may cause patellar displacement. Quad-muscle strengthening is often recommended.[10,33] The "quads" include the vastus medialis, vastus medialis obliquus (VMO), vastus intermedius, vastus lateralis and rectus femoris. Our study focused on vastus medialis oblique muscle. The role of the VMO among the thigh quadriceps muscle is mainly reported in the studies on the patellofemoral pain disorders, where the weakening of the VMO allows the patella to track too far laterally and causes the malalignment of the patella and abnormal lateral displacement.[34,35] In literature, the effect of various exercises on muscle strength was investigated on specific muscles. Some studies focus on exercises of varying hip positions, while some studies compare the effects of OKC and CKC exercises. It is commonly reported that all these exercises provide an increase in muscle strength.[36,37] Balci *et al*., recorded an increase in peak strength values the end of the exercise programs assigned at different hip rotation positions.[15] Also they reported VMO muscle strengthening is a common treatment of lateral displacement of patella and it is used in combination with other exercises. No significant improvement in bracing group is because of while wearing the brace, the external moment occurs and stabilizes the patella to the trochlear groove and thereby the activation of the VMO decreases significantly.[38] This part of our study is in line with Choi *et al*., research who speculated application of brace for long time may cause weakening of the VMO.[34]

While the studies in literature discuss the effect of exercise on muscle strength in patients with LDP, its effect on proprioceptive ability has not been investigated. So we assessed and compare the effects of exercise and bracing on proprioception. In this study proprioception error significantly decreased in bracing group while reduction in exercise group was not significant. Neoprene knee cuff of brace move on the skin and lead to provoke different receptors. As well as in knee brace affecting mechanism, it was mentioned that stimulus of proprioception receptors by neoprene knee cuff increases proprioception inputs and as a result proprioception. So knee sleeves which make an appropriate stimulus or more effective pressure on the skin or under layers can improve proprioception.[39] Herrington *et al*., studied efficacy of neoprene knee sleeve on 20 healthy man and recorded improvement proprioceptive ability in bracing group than control group.[40] Shellock *et al*., reported that neoprene knee brace has a positive effect to correct patellar alignment.[1] Powers *et al*., reported the on-track brace significantly decreased pain without sizable changes in patellar alignment.[41] It seems

exercising lead to improvement of nervous and muscular coordination and reinforcement of nervous system and mechanoreceptors of proprioception that all of these factors can be helpful in improvement and reinforcement of proprioception.[42]

Balci *et al*., Reported that the improvement in proprioceptive senses provided by CKC exercise programs may be associated with the increase in muscle strength and the decrease in patellofemoral joint reaction strengths.[15] Our results are in line with previous studies.

CONCLUSIONS

This study demonstrated that both the exercise rehabilitation and patella brace improve strength and flexibility of stabilizer muscles of knee. However, exercise rehabilitation had better effects on muscle factors, whilst brace had better effects on proprioception. It is likely that better flexibility and more strength somehow reduced the stress on patellofemoral joint and it, in turn, alleviated the pain. It is also likely that relieving effects of knee brace and improvement of proprioception by it allows patients to be more physically active and it could have, more or less, effects similar to an exercise rehab program. Therefore both exercise and brace could be prescribed for patients with LDP. It seems application of the patellar brace combined with exercise might be a better treatment for patients suffered LDP because they could improve strength, flexibility and proprioception.

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REFERENCES

1. Shellock FG, Mullin M, Stone KR, Coleman M, Crues JV. Kinematic magnetic resonance imaging of the effect of bracing on patellar position: Qualitative assessment using an extremity magnetic resonance system. J Athl Train 2000;35:44-9.
2. Draper CE, Besier TF, Fredericson M, Santos JM, Beaupre GS, Delp SL, *et al*. Differences in patellofemoral kinematics between weight bearing and non weight bearing conditions in patients with patellofemoral pain. J Orthopaed Res 2011;29:312-7.
3. DeHaven KE, Lintner DM. Athletic injuries: Comparison by age, sport, and gender. Am J Sports Med 1986;14:218-24.
4. Song CY, Lin JJ, Jan MH, Lin YF. The role of patellar alignment and tracking *in vivo*: The potential mechanism of patellofemoral pain syndrome. Phys Ther Sport 2011;12:140-7.
5. Grelsamer RP. Patellar Malalignment. J Bone Joint Surg 2000;82:1639-50.
6. Shellock F. Effect of a patella-stabilizing brace on lateral subluxation of the patella: Assessment using kinematic MRI. Am J Knee Surg 2000;13:137-42.
7. Douciette SA, Goble EM. The effect of exercise on patellar tracking in lateral patellar compression syndrome. Am J Sport Med 1992;20:434-40.
8. White LC, Dolphin P, Dixon J. Hamstring length in patellofemoral pain syndrome. Physiotherapy 2009;95:24-8.
9. Fredericson M, Yoon K. Physical examination and patellofemoral pain syndrome. Am J Phys Med Rehab 2006;85:234-43.
10. Juhn MS. Patellofemoral pain syndrome: A review and guidelines for treatment. Am Fam Physician 1999;60:2012-22.
11. Kannus PA. Long patellar tendon: Radiographic sign of patellofemoral pain syndrome: A prospective study. Radiology 1992;185:859-63.
12. Farahmand F, Sejiavongse W, Amis AA. Quantitative study of the quadriceps muscles and trochlear groove geometry related to instability of the patellofemoral joint. J Orthop Res 2005;16:136-43.
13. Hyde TE, Gengenbach MS. Conservative management of sports injuries. USA: Jones and Bartlett Learning; 2007.
14. Arendt E. Anatomy and malalignment of the patellofemoral joint: Its relation to patellofemoral arthrosis. Clin Orthop Relat Res 2005;436:71-5.
15. Balci P, Tunay VB, Baltaci G, Atay AO. The effects of two different closed kinetic chain exercises on muscle strength and proprioception in patients with patellofemoral pain syndrome. Acta Orthop Traumatol Turc 2004;43:419-25.
16. Colvin AC, West RV. Patellar instability. J Bone Joint Surg 2008;90:2751-62.
17. Callaghan MJ, Bagley PJ, Selfe J, Oldham JA. The effects of patellar taping on knee joint proprioception. J Athl Train 2002;37:19-24.
18. Martin TJ. Technical report: Knee brace use in the young athlete. Pediatrics 2001;108:503-7.
19. Larsen B, Andreasen E, Urfer A, Mickelson MR, Newhouse KE. Patellar taping: A radiographic examination of the medial glide technique. Am J Sport Med 1995;23:465-71.
20. Worrell T, Ingersoll CD, Bockrath-Pugliese K, Minis P. Effect of patellar taping and bracing on patellar position as determined by MRI in patients with patellofemoral pain. J Athl Train 1998;33:16-20.
21. Dejour H, Walch G, Nove-Josserand L, Guier C. Factors of patellar instability: An anatomic radiographic study. Knee Surg Sport Traumatol Arthrosc 1994;2:19-26.
22. Lin DH, Lin YF, Chai HM, Han YC, Jan MH. Comparison of proprioceptive functions between computerized proprioception facilitation exercise and closed kinetic chain exercise in patients with knee osteoarthritis. Clin Rheumatol 2007;26:520-8.
23. Scopaz KA, Piva SR, Gil AB, Woollard JD, Oddis CV, Fitzgerald GK. Effect of baseline quadriceps activation on changes in quadriceps strength after exercise therapy in subjects with knee osteoarthritis. Arthritis Rheum 2009;61:951-7.
24. Piva SR, Fitzgerald GK, Wisniewski S, Delitto A. Predictors of pain and function outcome after rehabilitation in patients with patellofemoral pain syndrome. J Rehabil Med 2009;41:604-12.
25. Grygorowicz M, Kubacki J, Pilis W, Gieremek K, Rzepka R. Selected isokinetic tests in knee injury prevetion. Biol Sport 2010;27:47-51.
26. Bakhtiari RA. Evaluation of static and dynamic balance and knee proprioception in young professional soccer players. Ann Biol Res 2012;3:2867-28.
27. Myer GD, Ford KR, Brent JL, Hewett TE. Differential neuromuscular training effects on ACL injury risk factors in. BMC Musculoskelet Disord 2007;8:39.
28. Subasi SS, Gelecek N, Kasnakoglu G. Effect of different warm-up periods on knee proprioception and balance in healthy young individuals. J Sport Rehabil 2008;17:186-205.
29. Dewhurst P. Conservative management of patellofemoral pain syndrome: What is the best approach? Clin Chiropr 2009;12:79-82.
30. Smith AD, Stroud L, McQueen C. Flexibility and anterior knee pain in adolescent elite figure skaters. J Pediatr Orthop 1991;11:77-82.
31. 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 2005;35:793-801.
32. Witvrouw E, Lysens R, Bellemans J, Cambier D, Vanderstraeten G. Intrinsic risk factors for the development of anterior knee pain in an

athletic population: A two-year prospective study. Am J Sport Med 2000;28:480-9.
33. Callaghan MJ, Oldham JA. The role of quadriceps exercise in the treatment of patellofemoral pain syndrome. Sports Med 1996;21:384-91.
34. Choi EH, Kim KK, Jun AY, Choi EH, Choi SW, Shin KY. Effects of the off -loading brace on the activation of femoral muscles-A preliminary study. Ann Rehabil Med 2011;36:887-96.
35. Collado H, Fredericson M. Patellofemoral pain syndrome. Clin Sport Med 2010;29:379-98.
36. Hazneci B, Yildiz Y, Sekir U, Aydin T, Kalyon TA. Efficacy of isokinetic exercise on joint position sense and muscle strength in patellofemoral pain syndrome. Am J Phys Med Rehab 2005;84:521-7.
37. Loudon JK, Gajewski B, Goist-Foley HL, Loudon KL. The effectiveness of exercise in treating patellofemoral-pain syndrome. J Sport Rehabil 2004;13:323-42.
38. Rannou F, Poiraudeau S, Beaudreuil J. Role of bracing in the management of knee osteoarthritis. Curr Opin Rheumatol 2010;22:218-22.
39. Mohammadi Asl J, Kahrizi S, Ebrahimi E, Faghihzadeh S. The effect of short-term usage of rigid neoprene knee sleeve and soft neoprene knee sleeve on knee joint position sense perception after reconstruction surgery of anterior cruciate ligament. World J Sport Sci 2008;1:42-7.
40. Herrington L, Simmonds C, Hatcher J. The effect of a neoprene sleeve on knee joint position sense. Res Sports Med 2005;13:37-46.
41. Powers CM, Ward SR, Chan LD, Chen YJ, Terk MR. The effect of bracing on patella alignment and patellofemoral joint contact area. Med Sci Sport Exer 2004;36:1226-32.
42. Rahnama N, Lees A, Bambaecichi E. A comparison of muscle strength and flexibility between the preferred and non-preferred leg in English soccer players. Ergonomics 2005;48:1568-75.

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