The Effect of an Exercise Program in Conjunction with Short Period Patellar Taping on Pain, EMG Activity, and Muscle Strength in Patellofemoral Pain Syndrome

"Short-period patellar taping in patellofemoral pain syndrome"

Defne Kaya PT MSc PhD [1,2], Michael J. Callaghan PT PhD [2], Huseyin Ozkan MD Assist. of Prof. [3], Fatih Ozdag Assoc. of Prof. [4], Ozgur Ahmet Atay MD Prof. [5], Inci Yuksel PT PhD Prof. [6], Mahmut Nedim Doral MD Prof. [1,5].

[1] Hacettepe University, Faculty of Medicine, Department of Sports Medicine, Ankara, Turkiye.

[2] Centre for Rehabilitation Science, University of Manchester, Manchester, England.

[3] GATA Military Medical Faculty, Department of Orthopaedic and Traumatology, Ankara, Turkiye.

[4] GATA Haydarpaşa Hospital, Department of Neurology, Istanbul, Turkiye.

[5] Hacettepe University, Faculty of Medicine, Department of Orthopaedic and Traumatology, Ankara, Turkiye.

[6] Hacettepe University, Faculty of Health Sciences, Department of Physical Therapy and Rehabilitation, Orthopaedic Rehabilitation, Ankara, Turkiye.

Corresponding authors:

Defne Kaya PT MSc PhD Hacettepe University, Faculty of Medicine, Department of Sports Medicine, Ankara, Turkiye. e-mail: defne@hacettepe.edu.tr Phone: +90 (312) 3051347.

Mahmut Nedim Doral MD Prof Hacettepe University, Faculty of Medicine, Department of Orthopaedic and Traumatology, and Head of the Department of Sports Medicine Ankara, Turkiye. e-mail: ndoral@hacettepe.edu.tr Phone: +90 (312) 3051209 &+90 (312) 3051347.

Abstract

Background: M^c^Connell recommended patellar tape be kept on all day, until patients have learned how to activate their VMO during an exercise program. This application may pose problems as there may be some patients for whom prolonged taping is inadvisable or even contraindicated due to skin discomfort, irritation or allergic reaction.**Hypothesis:** Wearing patellofemoral tape for a shorter duration of time for an exercise program would be just as beneficial as a prolonged taping application. **Study design:** A designed as prospective cohort study.**Methods:** Twelve patients and sixteen healthy people participated. Patients underwent short-period patellar taping plus an exercise program for three months. Numeric pain rating, muscle strength of the knee extensors, and EMG activity of vastus lateralis (VL) and the vastus medialis obliqus (VMO) were evaluated. **Results:** There were significant differences in EMG activity (p=0.04) and knee extensors muscle strength (p= 0.03) between involved and uninvolved sides before treatment. After treatment, pain scores decreased and there were no significant differences between involved and uninvolved sides in EMG activity (p=0.68) and knee extensors strength (p=0.62). Before treatment, mean VMO activation started significantly later than VL in patients compared with the matched healthy control group (p=0.00). After treatment, these differences were non-significant (p=0.08). **Conclusion:** This study demonstrated that short-period patellar taping plus an exercise program improved VMO and VL activation. **Clinical relevance:** A shorter period of taping for the exercise program is just as beneficial as a prolonged taping application.

Key words: Patellar taping, patellofemoral pain syndrome, physical therapy techniques, isokinetic muscle strength, electromyography.

Introduction

Abnormal lateral tracking of the patella has been proposed as a contributing factor in the etiology of patellofemoral pain syndrome (PFPS). Abnormal lateral tracking may increase patellofemoral contact pressure and precipitate pathology in the patellofemoral articular cartilage.[1,7,14,24,26,28] Correct alignment of the patella may depend in part upon the balance between the vastus medialis obliqus (VMO) and vastus lateralis (VL) muscles, so an imbalance in the activity of the VMO relative to the VL is one proposed mechanism for abnormal patellar tracking.[5] Generalized quadriceps muscle weakness may result in malposition of the patella.[12,13] The timing of VMO muscle activity affects muscle length at contraction initiation, which may affect muscle force production.[23]

Many physical therapists use patellar taping as described by McConnell.[19] Taping has been shown to increase (or correct timing of) the activity levels of VMO relative to VL,[14,16] increase the quadriceps strength,[8] enhance neuromuscular recruitment[20] and reduce pain.[7, 9]

The literature search identified five reports that have assessed the effect of a rehabilitation program plus patellar taping. Three of these studies that investigated the effect of patellar taping and exercise showed that patellar taping alone did not improve discharge rate, while exercises plus patellar taping had better pain and functional scores after treatment.[4,6,27] In contrast, two other studies showed no significant differences between two groups that received either exercises or exercises plus patellar taping.[15,18] All these studies used patellar taping, in conjunction with exercise, but there were differences in the duration of tape use. In Cowan et al and Whittingham et al, patients used tape all day; it is unclear in the other studies for how long the tape was used.[6, 27]

M^cConnell recommended that the patellar tape be kept on all day, every day, until patients learned how to activate their VMO with an exercise program.[10,20] The tape is removed with care in the evening, allowing the skin time to recover. This may pose problems for some patients in whom prolonged taping is inadvisable or even contraindicated due to skin discomfort, irritation or allergic reaction.

The aim of this study was to investigate the effect of an exercise program in conjunction with short-period of patellar taping on pain, EMG activity of VL and VMO and knee extensor muscle strength in patients with PFPS.

Methods

Subjects

Twelve males with patellofemoral pain syndrome were referred from the orthopaedic departments. All patients had unilateral patellofemoral pain; the uninvolved knee was also tested for purposes of comparison. Sixteen healthy males were recruited as control subjects with the dominant extremity evaluated for purposes of comparison. Each subject performed a single leg landing from a 20cm high wooden box. The lower extremity the subject chose to land on for two out of three trials was defined as the dominant lower extremity.[3] A sample size calculation was performed for isokinetic muscle strength. Using data from Clark et al, from an exercise plus patellar taping group with δ= 94 and σ=141 Nm at 80% power and alpha level 0.05, we estimated a sample size of n=20.[4] Written informed consent was obtained.

Inclusion criteria

Clinical assessment was performed by an orthopaedic surgeon. Patients were included in this study if the following criteria were fulfilled:

1) The onset of pain was longer than six months,

2) Characteristic clinical signs of the syndrome (i.e., retropatellar pain, crepitation and pain on patellar grinding),

3) Age between 15-45 years,

4) Normal radiography and magnetic resonance scan if performed.

Exclusion criteria

Patients and controls were excluded for the following criteria:

1) History or clinical evidence of patellofemoral dislocation, subluxation, or osteoarthritis,

2) Dysfunction of knee ligaments, bursae, menisci, patellar tendon or synovial plicae,

3) History of knee or lower extremity surgery, including arthroscopy,

4) Radiographic evidence of osteoarthritis in any compartment of the knee.

Assessment

Affected and unaffected knee of the patients were evaluated. There were no patients with radiographically diagnosed osteoarthritis. Participants performed a 5-minute bicycle warm-up after the test process.

Pain assessment, isokinetic knee extension torque, and EMG recording (during the isometric contraction) were performed pre-treatment and 3 months post-treatment for patients with PFPS. Healthy participants were evaluated by isokinetic knee extension torque, and EMG recording of the VMO and VL (during the isometric contraction).

Pain

An 11-point numeric rating scale was used to assess pain in 1 cm intervals, anchored on the left with the phrase "No Pain" and on the right "Worst Imaginable Pain."[17] Patients rated their worst level of pain in the past 24 hour at baseline.

EMG Recording- Onset timing determination

Onset activity of VMO and VL was recorded using electrodes as previously described.[5, 6] To test the EMG signal from the VMO and VL of the quadriceps muscle, during maximal voluntary isometric contractions at 60 degrees knee flexion, the following procedure was used. An oscilloscope program with two channels in free run (Dantec Keypoint®, Denmark). Silver/Silver chloride cup electrodes (Medtronic 9012E2311, Denmark) were placed over the muscle belly of VMO muscle 4 cm superior to and 3 cm medial to the superomedial patella border and muscle belly of VL muscle 10 cm superior to and 6 to 8 cm lateral to the superior border of patella as described Cowan et al. Inter-electrode distance was 22 mm.[5] The ground electrodes were placed over the tibial tubercle and tibia 15 cm away from each active electrode. The electrical impedance was reduced below 5 KΩ by shaving and cleaning the skin with alcohol. The sweep speed was 160 ms and sensitivity was 0.2mV per division. The amplifier bandwidth was preset from 5-10.000 Hz in each channel at sampled at 1000 Hz.

The participants were instructed to relax until a flat electrical base line was observed on the EMG machine so that the onset of EMG activity was not obscured by movement artifact or noise before each trial. The participants performed an isometric contraction of the knee extensors for 5 seconds after a verbal command. The first deflection from the base line was accepted as the onset of EMG activity. The relative difference in the time of onset of EMG activity of VMO and VL was quantified during the task. A negative value indicates VMO onset before VL.[11] EMG onsets and the relative differences were averaged over the three repetitions. Participants were rested 1 minute between each isometric contraction.

Muscle Strength

The isokinetic strength of the knee extensors was determined bilaterally at angular velocity 60 degrees/s (Cybex®). The test was performed with the participants seated with 70 degrees hip flexion and knee 90 degrees flexion. The Cybex® monitor allowed visual feedback. Standardized verbal encouragement was given during the test performance. Participants were rested 5 minutes between each isokinetic repetitions. Three repetitions of concentric peak extension torque were performed for the mean torque.

Treatment

Patients performed an exercise program in conjunction with short-period patellar taping for three months. Patients were seen once a week by a physiotherapist.

Patellar Taping

Patellar taping was performed by a physiotherapist trained in the technique described by M^{c}Connell to correct patellar malposition.[10,20] Undertape (M-Wrap®, 70mm X 27.5 m, Mueller®, USA) was first applied, taking care not to place any tension on the patient's skin followed by corrective tape (Protape®, 38mm X 10 m, Norgesplaster AS®, Vennesla, Norway). Patients were advised to apply the patellar tape before every exercise set and remove the patellar tape at the end of the each exercise set during the three month program. The usual length of the time for taping use was 30 minutes for each of three exercise sessions performed every day (90 minutes total per day).

Exercise Program

A home exercise program was designed to improve VMO activation (see Table 1).[19,20,24] Neuromuscular retraining exercises included isometric quadriceps sitting, straight leg raise with ankle weights, terminal knee extension in a sitting position with ankle weights, wall squats with ball between the knees, step-down exercises (20 cm) (backward, forward and sideways), single-leg balance exercises in different knee angle with Theraband® Stability Trainer (blue). Static stretching exercises were prescribed for the quadriceps, iliotibial band, hamstrings and gastrocnemius muscles. Patients performed four sessions of 25 repetitions of each isometric exercise per day. Isotonic and stretching exercises were performed three sessions of 10 repetitions per a day. "Hold" time of isometric and isotonic exercises was five seconds. "Hold" time of stretching exercises was 10 seconds.[2] Patients were called by telephone weekly to check their compliance with the exercise program. The patients used a daily exercise check list and recorded their performance.

Statistical Analysis

All data were analyzed with the Statistical Package for the Social Sciences (SPSS) version 14.0 (Chicago, IL). The t test for paired samples was used to compare unaffected and affected side pre- and post-treatment. Independent-samples t test was used to compare affected and dominant extremity of controls. Wilcoxon test was used compared before and after treatment. P-values less than 0.05 were considered significant.

Results

Twelve patients completed the rehabilitation program and all assessment procedures. There were no adverse effects reported from the patellar taping and exercises program. Table 2 shows the means and standard deviations for demographic variables and anthropometric characteristics of patients and healthy control group.

Pain

Pain average was 6.33 ± 2.71 at the initial assessment and decreased to 0.58 ± 0.79 ($p=0.01$). Patients clearly felt less pain (decrease from 6.3 to 0.58 on a VAS). This is both clinically (treatment effect 3.18) and statistically significant ($p = 0.001$).

Electromyographic Data

The healthy control group showed a VMO-VL onset timing difference of -0.25: the VMO fired 0.25 ms before the VL. VMO activation started significantly later (5 ms) than the VL in the pre-treatment assessment period ($p=0.04$). The onset timing difference was significantly improved post-treatment to 0.25ms ($p = 0.04$) (Table 3). In addition, the EMG onset timing difference (pre-treatment and post-treatment) showed an improvement from 4 ms to 0.75 ms ($Z=-2.002$, $p<0.05$). Before treatment, VMO activation started significantly later than VL in the affected side of patients than the dominant extremity of healthy control group ($p=0.00$) (Table 3). After treatment, there was no significant difference between VMO - VL onset timing of the affected side of patients and the dominant extremity of the control group ($p = 0.08$).

Muscle Strength

There were no significant differences between patients and controls before treatment ($p=0.31$). The knee extensors muscle strength significantly increased after treatment (PFPS patients' affected side and dominant side of control group $p=0.02$) (Table 4). The knee extensors muscle strength of the affected side (pre-treatment and post-treatment) showed an improvement from 138.33 to 160.75 Nm ($Z=-2.237$, $p<0.05$). The significant differences between affected and unaffected legs before treatment ($p=0.03$) were no longer significant post treatment ($p=0.62$) (Table 3).

Discussion

This study investigated the effect of an exercise program in conjunction with short-period patellar taping on pain, EMG activities and isokinetic knee extension torque in patients with PFPS. Patients usually prefer shorter periods of taping rather than taping all day. This study demonstrated that an exercise program in conjunction with short-period patellar taping for three months was efficacious.

The present study provided three clinically significant findings. First, the pain outcome was based on improvements in the numeric rating scale during a nominated activity which always made their pain worse. For PFPS, it is usually stair climbing, squatting, or kneeling. Five studies have reported the effects of exercise plus patellar taping on pain.[4,6,15,18,27] Patients in four studies received six to 20 sessions of physiotherapy over a four week period. At the post treatment assessment, Kowall et al showed that pain scores significantly decreased.[18] Two studies showed that exercises plus taping significantly lowered pain scores at end of the treatment.[15,27] Harrison et al assessed patients three months after treatment showing that pain decreased most at one month.[15] Clark et al provided six sessions of physiotherapy over three months.[4] Pain scores significantly improved but taping alone had no effect. Taping plus an exercise program was significantly more effective than taping alone.[4] Cowan et al were randomly allocated patients to physical therapy (M^{c}Connell-based) or placebo intervention groups for six weeks.[6] The M^{c}Connell-based physical therapy intervention group improved pain scores and functional level more than the placebo intervention group.[6] These pain results resemble those of this study. VMO contraction improved by taping may allow pain-free exercise as originally theorized by M^{c}Connell.[19] Taping may be a means of pain free strengthening of the knee extensors during a daily exercise program.

Second, two previous studies have investigated the effect of taping plus exercise program on VMO activity.[6,18] Kowall et al showed significantly increased activity in both the VMO and VL muscles after taping plus an exercise program. It was unclear which muscle had greatest activation from their results.[18] Cowan et al described improvements in the onset latency between the VMO and VL muscles after patellar taping and progressive functional retraining using EMG biofeedback.[6] The onset of VL activity occurred before that of VMO in the two groups before treatment. After treatment, VMO activity occurred before that of VL during stair-stepping in the physical therapy treatment group. There was no change in the time of EMG onset in the placebo group. However, it is unclear which therapeutic parameter is more effective.[6] This study demonstrated that VMO activity significantly increased during the intervention period after taping plus an exercise program, but different procedures were used to collect and analyze the EMG activity. For example, Cowan et al[6] and Kowall et al[18] studied step-up and step-down stairs activity, while we studied isometric contraction at 60 degrees knee flexion. We chose this task because the highest average torque is produced at this knee angle.[21]

Neptune et al demonstrated that a VMO timing delay was associated with a significant increase in lateral loading of the patellofemoral joint.[22] It is possible that our treatment program was able to reduce lateral femoral loading due to an increase in VMO activity by decreasing pain. Our rehabilitation program improved VMO activation supporting M[c]Connell's theory that pain-free exercise might be due to improving VMO contraction. The VMO may be activated earlier due to a cutaneous or proprioceptive stimulation from patellar taping.

Finally, there have been two studies in the literature demonstrating the effect of taping plus an exercise program on knee extensors muscle strength.[4,18] Clark et al showed a statistically significant ($p < 0.001$) improvement of about 30Kg/Force after 3 months of taping treatment.[4] Kowall et al also showed a significant improvement in quads strength ($p < 0.05$) although no raw data were presented. [18] In our study, the knee extensors muscle strength of the affected side (pre-treatment and post-treatment) showed an improvement from 138.33 to 160.75 Nm ($p<0.05$). These studies showed significantly increased isokinetic muscle strength in knee extensors after taping plus exercise program. Our result concurs with these studies. After treatment, affected side of PFPS patients did not reach the level of knee extensors muscle strength of healthy controls. Suter et al found a direct relationship between quadriceps inhibition and knee pain.[25] They concluded that pain was related to the amount of muscle inhibition and contribute to the inhibition. Suter et al emphasized that pain is responsible for the muscle inhibition observed in patients with PFPS. After pain improvement, time is required to fully restore muscle function.[25]

The prime limitation of our study was that a group did not receive the exercise program alone without taping. The secondary limitation is that the sample size was small. A post hoc power calculation was conducted with EMG and peak torque data: For the EMG values—a difference of 4.75, a pooled standard deviation of 5, an alpha level of .05, and a sample size of 12—the power was 85%. For the peak torque data—a mean difference of 22, a standard deviation of 37, an alpha level of .05, and a sample size of 12—the power was 45%.

Conclusion

An exercise program in conjunction with short- period patellar taping was efficacious. Taping increased (or corrected the timing of) the VMO relative to VL, increased quadriceps strength, enhanced neuromuscular recruitment, and reduced pain.

References

1. Arroll B, Ellis-Pegler E, Edwards A, Sutcliffe G. Patellofemoral pain syndrome. A critical review of the clinical trials on nonoperative therapy. *Am J Sports Med.* 1997;25:207-212.

2. Borms J, Roy P, Santens JP, Haentjens A. "Optimal duration of static stretching exercises for improvement of coxo-femoral flexibility" *Journal of Sports Sciences*, 1987: 5(1); 39 – 47.

3. Carcia CR, Drouin JM, Houglum PA. The Influence of a foot orthotic on lower extremity transverse plan kinematics in collegiate female athletes with pes planus. *Journal of Sports Science and Medicine* 2006; 5: 646-655.

4. 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;59:700-704.

5. Cowan, SM, Bennell, KL, Hodges PW, Crossley KM, M[c]Connell J. Delayed onset of electromyographic activity of vastus lateralis compared to vastus medialis obliquus in subjects with patellofemoral pain syndrome. *Arch Phys Med Rehabil.* 2001**;**82:183–189.

6. Cowan SM, Bennell K, Crossley K, Hodges PW, M[c]Connell J. Physical therapy alters recruitment of the vasti in patellofemoral pain syndrome. *Med Sci Sports Exer.* 2002;34(12):1879-1885.

7. Crossley K, Cowan SM, Bennell KL, M[c]Connell J. Patellar taping: Is clinical supported by scientific evidence? *Man Ther*. 2000;5:142-150.

8. Crossley K, Bennell K, Green S, M[c]Connell J. A systematic review of physical interventions for patellofemoral pain syndrome. *Clin J Sport Med.* 2001;11(2):103-110.

9. Crossley K, Bennell K, Green S, Cowan S, M[c]Connell J. Physical therapy for patellofemoral pain: A randomized, double-blinded, placebo-controlled trial. *Am J Sports Med.* 2002;30(6):857-865.

10. Crossley K, Bennell K, M[c]Connell J. Patellofemoral Joint. Kolt GS, Snyder-Mackler L, editors. In *Physical Therapies in Sport and Exercise*, London: Churchill Livingstone, 2003, p.319-418.

11. Crossley KM, Cowan SM, Bennell KL, McConnell J. Knee flexion during stair ambulation is altered in individuals with patellofemoral pain. J Orthop Res. 2004 Mar; 22(2): 267-274.

12. Dvir Z, Halperin N, Shklar A, Robinson D. Quadriceps function and patellofemoral pain syndrome. Part I: Pain provocation during concentric and eccentric isokinetic activity. *Isokinetics and Exercise Science.* 1991;11(1):26-30.

13. Dvir Z, Halperin N, Shklar A, Robinson D, Weissman I, Ben-Shosan I. Concentric and eccentric torque variations of the quadriceps femoris in patello-femoral pain syndrome. *Clin Biomech.* 1990;5(2):68-72.

14. Gilleard W, McConnell J, Parsons D. The effect of patellar taping on onset of vastus medialis obliquus and vastus lateralis muscle activity in persons with patellofemoral pain. *Phys Ther.* 1998;78:25-32.

15. Harrison EL, Sheppard MS, McQuarrie AM. A randomized controlled trial of physical therapy treatment programs in patellofemoral pain syndrome. *Physiotherapy Canada.* 1999;51:93-100.

16. Herrington L, Payton CJ. Effect of corrective taping of the patella on patients with patellofemoral pain. *Physiotherapy.* 1997;83(11):566-572.

17. Jensen MP, Turner JA, Romano JM. What is the maximum number of levels needed in pain intensity measurement? *Pain.* 1994;58:387–392.

18. Kowall MG, Kolk G, Nuber GW, Cassisi JE, Stern SH. Patellar taping in the treatment of patellofemoral pain-A prospective randomized study. *Am J Sports Med.* 1996;24(1):61-65.

19. M^{c}Connell J. The management of the chondromalacia patellae:A long term solution. *Aust J Physiother.* 1986;32:215-223.

20. M^{c}Connell J. Management of patellofemoral problems. *Man Ther.* 1996;1:60-66.

21. Murray MP, Baldwin JM, Gardner GM, Sepic SB, Downs WJ. Maximum isometric knee flexor and extensor muscle contractions: Normal patterns of torque versus time. *Phys Ther.* 1997;57(6):637-643.

22. Neptune RR, Wright IC, Bogert AJ. The influence of orthotics devices and vastus medialis strength and timing on patellofemoral loading during running. *Clin Biomech.* 2000;20:611-618.

23. Nordin M, Frankel V. Basic Biomechanics of the Musculoskeletal System, London, England: Lippincott Williams & Wilkins, 1989.

24. Powers CM. Rehabilitation of patellofemoral joint disorders: A critical review. *J Orthop Sport Phys Ther.* 1998;28(5):345-353.

25. Suter E, Herzog W, De Souza K, Bray R. Inhibition of the quadriceps muscles in patients with anterior knee pain. *J Appl Biomech.* 1998;14:360–373.

26. Thomee R, Augustsson J, Karlsson J. Patellofemoral pain syndrome: A review of current issues. *Sports Med.* 1999;28:245-262.

27. Whittingham M, Palmer S, Macmillan F. Effects of taping on pain and function in patellofemoral pain syndrome: A randomized controlled trial. *J Orthop Sport Phys Ther.* 2004;34:504-510.

28. 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 Sports Med.* 2000;28(4):480-489.

TABLES

Table 1. Exercise Program

Exercises	Duration
Stretches (All sessions) ● Hamstring stretch ● Quadriceps stretch ● Calf and iliotibial band stretch	3 sets of 10 repetitions/10-s hold
Weeks 1-2 ● Wall squat (0°_40° of knee flexion) ● Quadriceps isometric ● Straight leg raises	 15 repetitions/10-s hold 4 sets of 25 repetitions 3 sets of 10 repetitions
Weeks 3-4 ● Wall squat (0°_60° of knee flexion) ● Quadriceps isometric ● Straight leg raises ● Terminal knee extension	 15 repetitions/10-s hold 4 sets of 25 repetitions 3 sets of 10 repetitions 3 sets of 10 repetitions
Weeks 4-5 ● Continued previous exercises ● Mini-squat (0°_30° of knee flexion) ● Lateral step down	 3 sets of 10 repetitions 3 sets of 10 repetitions
Weeks 6 to 8 ● Mini-squat (0°_45° of knee flexion) ● Lateral step down with Thera-band resistance behind knee pulling anteriorly ● Backward walk with Thera-band resistance around ankles (subjects stand with slight knee flexion and take steps backward with resistance between ankles) ● Lateral step down off 4-in step with Thera-band resistance behind knee pulling anteriorly ● Single-leg stance	 3 sets of 10 repetitions 3 sets of 10 repetitions 3 sets of 10 repetitions 3 sets of 10 repetitions 3 sets of 10 repetitions
Weeks 8 and 10 ● Mini-squat (0°_60° of knee flexion) ● Anterior step down with Thera-band resistance behind knee pulling posteriorly ● Side stepping with Thera-band resistance around ankles ● Forward lunges with push-off (subjects lunge onto step to 40° of knee flexion and push off to starting position	 3 sets of 10 repetitions 3 sets of 10 repetitions 3 sets of 10 repetitions 3 sets of 10 repetitions
Weeks 10 to 12 ● Single-leg mini-squat (0°_30° to 0°-45° of knee flexion) ● Anterior/Lateral and sideway steps with Thera-band resistance behind knee pulling. ● Split squat with Theraband® Stability Trainer (blue) ● Forward lunges to ground level.	 3 sets of 10 repetitions 3 sets of 10 repetitions 3 sets of 10 repetitions 3 sets of 10 repetitions

Table 2. Means, standard deviation and percentage distribution for demographic variables of patients and control group.

Variables	Patients (n=12)	Control group (n=16)
	(Mean±SD)	**(Mean±SD)**
Age (years)	26.08 ± 6.49	22.37±2.21
Mass (kg)	72.83 ± 8.98	76.62±16.10
Height (cm)	173.75 ± 5.66	176.00±7.32

SD: Standard deviation

Table 3. Descriptive and compare values of the EMG onset activity and the peak torque of the M. Quadriceps Femoris obtained for affected side and unaffected side of the patients (pre-treatment and post-treatment).

	EMG Onset Activity (ms) (VMO - VL)			**Peak Torque (Nm)** (Quadriceps Femoris) 60º.s^{-1} extension		
	Affected side	**Unaffected side**		**Affected side**	**Unaffected side**	
	(Mean±SD)	**(Mean±SD)**	**p***	**(Mean±SD)**	**(Mean±SD)**	**p***
Pre-treatmen	5.00±6.04	1.00±4.47	**0.04**	138.33±45.27	155.67±45.53	**0.03**
Post-treatmen	0.25±4.27	-0.67±1.23	0.68	160.75±30.25	181.75±39.04	0.62

SD: Standard deviation, *: paired sample t test

Table 4. Descriptive and compare values of the EMG onset activity and the peak torque of the M. Quadriceps Femoris obtained for affected side of the patients (pre-treatment and post-treatment data) and dominant extremity of control group.

	EMG Onset Activity (ms) (VMO - VL)				**Peak Torque (Nm)** (Quadriceps Femoris) 60º.s^{-1} extension			
	Affected side	**Dominant side of control**			**Affected side**	**Dominant side of control**		
	(Mean±SD)	**(Mean±SD)**	**F**	**p****	**(Mean±SD)**	**(Mean±SD)**	**F**	**p****
Pre-treatmen	5.00±6.04	-0.25±2.35	15.01	**0.00**	138.33±45.27	179.12±55.38	1.04	0.31
Post-treatment	0.25±4.27	-0.25±2.35	3.15	0.08	160.75±30.25	179.12±55.38	6.23	**0.02**

SD: Standard deviation, **: independent t test