[Sports Physical Therapy]

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

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Background: McConnell recommended that patellar tape be kept on all day, until patients learn how to activate their vastus medialis obliquus (VMO) during an exercise program. This application may pose problems because prolonged taping may be inadvisable for some patients or even contraindicated owing to skin discomfort, irritation, or allergic reaction.

Hypothesis: Wearing patellofemoral tape for a shorter duration during an exercise program would be just as beneficial as a prolonged taping application.

Study Design: Prospective cohort.

Methods: Twelve patients and 16 healthy people participated. Patients underwent short-period patellar taping plus an exercise program for 3 months. Numeric pain rating, muscle strength of the knee extensors, and electromyogram activity of the vastus lateralis and VMO were evaluated.

Results: There were significant differences in electromyogram activity (P = .04) and knee extensor muscle strength (P = .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 electromyogram activity (P = .68) and knee extensor strength (P = .62). Before treatment, mean VMO activation started significantly later than that of vastus lateralis, as compared with the matched healthy control group (P = .01). After treatment, these differences were nonsignificant (P = .08).

Conclusion: Short-period patellar taping plus an exercise program improves VMO and vastus lateralis activation.

Clinical Relevance: A shorter period of taping for the exercise program may be as beneficial as a prolonged taping application.

Keywords: patellar taping; patellofemoral pain syndrome; physical therapy techniques; isokinetic muscle strength; electromyography

Abnormal lateral tracking of the patella has been proposed as a contributing factor in the cause of patellofemoral pain syndrome (PFPS). Abnormal lateral tracking may also increase patellofemoral contact pressure and precipitate pathology in the patellofemoral articular cartilage.[1,13,22,24,26] Correct alignment of the patella may depend in part on the balance between the vastus medialis obliquus (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.[6] Generalized quadriceps muscle weakness may result in malposition of the patella.[11,12] The timing of VMO muscle activity affects muscle length

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at contraction initiation, which may affect muscle force production.[21]

Many physical therapists use patellar taping as described by McConnell.[17] Taping has been shown to increase, or correct the timing of, the activity levels of VMO relative to VL,[13] increase quadriceps strength,[8] enhance neuromuscular recruitment,[18] and reduce pain.[7]

The literature search identified 5 reports that assessed the effect of a rehabilitation program plus patellar taping. Three of these studies showed that patellar taping alone did not improve discharge rate but that exercises plus patellar taping yielded better pain and functional scores after treatment.[4,5,25] In contrast, the 2 other studies showed no significant differences between 2 groups that received exercises or exercises plus patellar taping.[14,16] All these studies used patellar taping in conjunction with exercise, but there were differences in the duration of tape use. In studies by Cowan et al and Whittingham et al, patients used tape all day; it was unclear how long the tape was used in the other studies.[5,25]

McConnell recommended that patellar tape be kept on all day, every day, until patients learn how to activate their VMO with an exercise program.[9,18] The tape is removed with care in the evening, allowing time for the skin to recover. Taping may pose problems for patients for whom prolonged taping is inadvisable or even contraindicated owing 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 patellar taping on pain, electromyogram (EMG) activity of VL and VMO, and knee extensor muscle strength in patients with PFPS.

METHODS

Participants

Twelve men with PFPS were referred from the orthopaedic departments. All patients had unilateral patellofemoral pain; the uninvolved knee was also tested for purposes of comparison. Sixteen healthy men were recruited as controls, with the dominant extremity evaluated for purposes of comparison. Each participant performed a single-leg landing from a 20-cm-high wooden box. The dominant lower extremity was defined as the lower extremity that the participant chose to land on for 2 of 3 trials.[3] A sample size calculation was performed for isokinetic muscle strength. We used data from Clark et al[4] from an "exercise plus patellar taping" group, with $\delta = 94$ and $\sigma = 141$ N·m at 80% power and an alpha level of .05; we estimated a sample size of 20. Written informed consent was obtained.

Inclusion Criteria

An orthopaedic surgeon performed the clinical assessment. Patients were included in this study if they fulfilled the following criteria: (1) onset of pain longer than 6 months, (2) characteristic clinical signs of the syndrome (ie, retropatellar pain, crepitation, and pain on patellar grinding), (3) age between 15 and 45 years, and (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; and (4) radiographic evidence of osteoarthritis in any compartment of the knee.

Assessment

The patients' affected and unaffected knees 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 pretreatment and 3 months posttreatment 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*.[15] At baseline, patients rated their worst level of pain during a nominated activity in the past 24 hours.

EMG Recording: Onset Timing Determination

Onset activity of VMO and VL was recorded with electrodes as previously described.[5,6] The following procedure was used to test the EMG signal from the VMO and VL of the quadriceps muscle during maximal voluntary isometric contractions at 60° of knee flexion. An oscilloscope program with 2 channels in free run (Keypoint, Dantec, Copenhagen, Denmark) and silver/silver chloride cup electrodes (9012E2311, Medtronic, Copenhagen, Denmark) were placed over (1) the muscle belly of VMO muscle 4 cm superior to and 3 cm medial to the superomedial patella border and (2) the muscle belly of VL muscle 10 cm superior to and 6 to 8 cm lateral to the superior border of patella, as described by Cowan et al. Interelectrode distance was 22 mm.[6] 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 milliseconds, and sensitivity was 0.2 mV per division. The amplifier bandwidth was preset from 5-10.000 Hz in each channel sampled at 1000 Hz.

The participants were instructed to relax until a flat electrical baseline was observed on the EMG machine so that the onset of EMG activity was not obscured by movement artifact

Table 1. Exercise program.

Exercises	Duration
Stretches (all sessions)	
Hamstring	3 × 10 repetitions; 10-second hold
Quadriceps	3 × 10 repetitions; 10-second hold
Calf and iliotibial band	3 × 10 repetitions; 10-second hold
Weeks 1-2	
Wall squat (0°-40° of knee flexion)	15 repetitions; 10-second hold
Quadriceps isometric	4 × 25 repetitions
Straight leg raises	3 × 10 repetitions
Weeks 3-4	
Wall squat (0°-60° of knee flexion)	15 repetitions; 10-second hold
Quadriceps isometric	4 × 25 repetitions
Straight leg raises	3 × 10 repetitions
Terminal knee extension	3 × 10 repetitions
Weeks 4-5	
Continued previous exercises	
Minisquat (0°-30° of knee flexion)	3 × 10 repetitions
Lateral step down	3 × 10 repetitions
Weeks 6-8	
Minisquat (0°-45° of knee flexion)	3 × 10 repetitions
Lateral step down with Thera-Band resistance behind knee pulling anteriorly	3 × 10 repetitions
Backward walk with Thera-Band resistance around ankles (ie, stand with slight knee flexion and take steps backward with resistance between ankles)	3 × 10 repetitions
Lateral step down off 4-in. (10.16-cm) step with Thera-Band resistance behind knee, pulling anteriorly	3 × 10 repetitions
Single-leg stance	3 × 10 repetitions
Weeks 8-10	
Minisquat (0°-60° of knee flexion)	3 × 10 repetitions
Anterior step down with Thera-Band resistance behind knee, pulling posteriorly	3 × 10 repetitions
Side stepping with Thera-Band resistance around ankles	3 × 10 repetitions
Forward lunges with push-off (ie, lunge onto step to 40° of knee flexion and push off to starting position)	3 × 10 repetitions
Weeks 10-12	
Single-leg minisquat (0°-30° to 0°-45° of knee flexion)	3 × 10 repetitions
Anterior/lateral and sideway steps with Thera-Band resistance behind knee pulling	3 × 10 repetitions
Split squat with Thera-Band Stability Trainer (blue)	3 × 10 repetitions
Forward lunges to ground level	3 × 10 repetitions

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 baseline 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 indicated VMO onset before VL.[10] EMG onsets and the relative differences were averaged over 3 repetitions. Participants rested 1 minute between each isometric contraction.

Muscle Strength

The isokinetic strength of the knee extensors was determined bilaterally at angular velocity 60° per second (Cybex, Medway, Massachusetts). The test was performed with the participants seated with 70° of hip flexion and 90° of knee flexion. The Cybex monitor allowed visual feedback. Standardized verbal encouragement was given during the test performance. Participants 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 3 months. A physiotherapist saw patients once a week.

Patellar taping. Patellar taping was performed by a physiotherapist trained in the technique described by McConnell to correct patellar malposition.[9,18] Undertape (7 cm × 27.5 m, M-Wrap, Mueller Sports Medicine, Prairie du Sac, Wisconsin) was first applied, taking care not to place any tension on the patient's skin, followed by corrective tape (38 mm × 10 m, Protape, Norgesplaster AS, Vennesla, Norway). Patients were advised to apply the patellar tape before every exercise set and to remove it at the end of each set during the 3-month program. The usual length of the time for taping use was 30 minutes for each of 3 exercise sessions performed every day (90 minutes total per day).

Exercise program. A home exercise program was designed to improve VMO activation (Table 1).[17,18,22] Neuromuscular retraining exercises included isometric quadriceps setting, 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), and single-leg balance exercises in different knee angles with Thera-Band Stability Trainer (blue; Hygenic Corporation, Akron, Ohio). Static stretching exercises were prescribed for the quadriceps, iliotibial band, hamstrings, and gastrocnemius muscles. Patients performed 4 sessions of 25 repetitions of each isometric exercise per day. Isotonic and stretching exercises were performed 3 sessions of 10 repetitions per day. Hold time of isometric and isotonic exercises was 5 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 checklist and recorded their performance.

Table 2. Demographics of patients and controls.

Variables	Patients (n, 12)	Controls (n, 16)
Age, years ± SD	26.08 ± 6.49	22.37 ± 2.21
Mass, kg ± SD	72.83 ± 8.98	76.62 ± 16.10
Height, cm ± SD	173.75 ± 5.66	176.00 ± 7.32

Statistical Analysis

All data were analyzed with the SPSS 14.0. The *t* test for paired samples was used to compare the unaffected and affected sides pretreatment and posttreatment. Independent-samples *t* test was used to compare the PFPS affected side and dominant extremity of controls. Wilcoxon signed ranks test was used to compare pretreatment and posttreatment. P values less than .05 were considered significant.

RESULTS

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

Pain

Pain average was 6.33 ± 2.71 at the initial assessment, and it decreased to 0.58 ± 0.79 (P = .01). The decrease from 6.33 to 0.58 on a visual analogue scale is not only clinically significant (treatment effect, 3.18) but statistically significant (P = .01).

Electromyographic Data

The healthy control group showed a VMO-VL onset timing difference of −0.25: That is, the VMO fired 0.25 milliseconds before the VL. In the PFPS group, VMO activation started significantly later (5 milliseconds) than the VL in the pretreatment assessment period (P = .04). The onset timing difference significantly improved posttreatment to 0.25 milliseconds (P = .04) (Table 3). In addition, the EMG onset timing difference (pretreatment and posttreatment) showed an improvement from 4 milliseconds to 0.75 milliseconds ($Z = -2.002$, $P < .05$). Before treatment, VMO activation started significantly later than VL in the affected side of patients than did the dominant extremity of healthy controls (P = .01) (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 = .08).

Table 3. Electromyogram onset activity and peak torque of the quadriceps femoris: Affected and unaffected sides (pretreatment and posttreatment).

	Affected Side	Unaffected Side	P^a
EMG onset activity,[b] ms			
Pretreatment	5.00 ± 6.04	1.00 ± 4.47	.04
Posttreatment	0.25 ± 4.27	−0.67 ± 1.23	.68
Peak torque,[c] N·m			
Pretreatment	138.33 ± 45.27	155.67 ± 45.53	.03
Posttreatment	160.75 ± 30.25	181.75 ± 39.04	.62

[a]Paired sample *t* test.
[b]Vastus medialis obliquus – vastus lateralis.
[c]Quadriceps femoris, 60° per second extension.

Table 4. Electromyogram onset activity and peak torque of the quadriceps femoris obtained for affected side of the patients (pretreatment and posttreatment data) and dominant extremity of control group.

	Affected Side	Dominant Side of Control	F	P^a
EMG onset activity,[b] ms				
Pretreatment	5.00 ± 6.04	−0.25 ± 2.35	15.01	.01
Posttreatment	0.25 ± 4.27	−0.25 ± 2.35	3.15	.08
Peak torque,[c] N·m				
Pretreatment	138.33 ± 45.27	179.12 ± 55.38	1.04	.31
Posttreatment	160.75 ± 30.25	179.12 ± 55.38	6.23	.02

[a]Independent *t* test.
[b]Vastus medialis obliquus – vastus lateralis.
[c]Quadriceps femoris, 60° per second extension.

Muscle Strength

There were no significant differences between patients and controls before treatment ($P = .31$). The isokinetic knee extensor muscle strength significantly increased after treatment (PFPS patients' affected side and dominant side of control group, $P = .02$) (Table 4). The isokinetic knee extensor muscle strength of the affected side (pretreatment and posttreatment) showed an improvement from 138.33 to 160.75 N·m ($Z = -2.237$, $P < .05$). The significant differences between affected and unaffected legs before treatment ($P = .03$) were no longer significant posttreatment ($P = .62$) (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 3 months was efficacious.

The present study provided 3 clinically significant findings. First, the pain outcome was based on improvements in the numeric rating scale during a nominated activity that always made their pain worse. For PFPS, it was usually stair climbing, squatting, or kneeling. Five studies have reported the effects of exercise plus patellar taping on pain.[4,5,14,16,25] Patients in 4 studies received 6 to 20 sessions of physiotherapy over a 4-week period. At the posttreatment assessment, Kowall et al showed that pain scores significantly decreased.[16] Two studies showed that exercises plus taping significantly lowered pain scores at the end of treatment.[14,25] Harrison et al assessed patients 3 months after treatment, showing that pain decreased most at 1 month.[14] Clark et al provided 6 sessions of physiotherapy over 3 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 randomly allocated patients to physical therapy (McConnell based) or placebo intervention groups for 6 weeks.[5] The McConnell-based physical therapy intervention group improved its pain scores and functional levels more than the placebo intervention group.[5] These pain results resemble those of the present study. VMO contraction improved by taping may allow pain-free exercise, as originally theorized by McConnell.[17] Taping may be a means of pain-free strengthening of the knee extensors during a daily exercise program.

Second, 2 studies have investigated the effect of taping plus an exercise program on VMO activity.[5,16] Kowall et al showed significantly increased activity in the VMO and VL muscles after taping plus an exercise program. It was unclear from their results which muscle had greatest activation.[16] 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.[5] The onset of VL activity occurred before that of VMO in the 2 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 was more effective.[5] 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[5] and Kowall et al[16] studied step-up and step-down stairs activity, whereas we studied isometric contraction at 60° of knee flexion. We chose this task because the highest average torque is produced at this knee angle.[19]

Neptune et al demonstrated that a VMO timing delay is associated with a significant increase in lateral loading of the patellofemoral joint.[20] It is possible that our treatment program was able to reduce lateral femoral loading because of an increase in VMO activity by decreasing pain. Our rehabilitation program improved VMO activation, supporting McConnell's theory that pain-free exercise might be due to improving VMO contraction. The VMO may be activated earlier owing to a cutaneous or proprioceptive stimulation from patellar taping.

Finally, 2 studies in the literature demonstrated the effect of taping plus an exercise program on knee extensor muscle strength.[4,16] Clark et al showed a statistically significant ($P < .001$) improvement of about 30 kg after 3 months of taping treatment.[4] Kowall et al also showed a significant improvement in quads strength ($P < .05$), although no raw data were presented.[16] In our study, the knee extensor muscle strength of the affected side (pretreatment and posttreatment) showed an improvement from 138.33 to 160.75 N·m ($P < .05$). Therefore, our results concur with these previous studies. After treatment, the affected sides of the PFPS patients did not reach the level of knee extensor muscle strength of the healthy controls. Suter et al found a direct relationship between quadriceps inhibition and knee pain.[23] They concluded that pain is related to the amount of muscle inhibition and so contributes 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.[23]

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 only 45%.

CONCLUSION

An exercise program in conjunction with short-period patellar taping is efficacious. Taping increases, or corrects the timing of, the VMO relative to VL and increases quadriceps strength, enhances neuromuscular recruitment, and reduces pain.

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