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Research Report

The Effect of Patellar Taping on the Onset of Vastus Medialis Obliquus and Vastus Lateralis Muscle Activity in Persons With Patellofemoral Pain

Background and Purpose. The purpose of this study was to investigate the effect of patellar taping on the onset of activity of the vastus medialis obliquus muscle (VMO) and the vastus lateralis muscle (VL). **Subjects and Methods.** Fourteen female subjects with patellar pain walked up and down stairs in two conditions: (1) with the patellofemoral joint of the painful lower extremity taped so that the pain was reduced by at least 50% on a pain provocation test and (2) without patellar taping. **Results.** When the patellofemoral joint was not taped, there was no difference in the onset of activity between the VMO and the VL during the step-up and step-down tasks. During the step-up task, the onset of VMO activity occurred earlier with taping but there was no change in the onset of VL activity with taping. During the step-down task, the onset of VMO activity occurred earlier and the onset of VL activity was delayed with taping. When the patellofemoral joint was taped, the VMO was activated earlier than the VL during the step-up and step-down tasks. **Conclusion and Discussion.** Taping of the patellofemoral joint in the manner used in this study changed the timing of VMO and VL activity in subjects with patellofemoral pain during step-up and step-down tasks. The earlier activation of the VMO may alter the movement of the patella, and further research is needed to determine whether this occurs and whether it is beneficial. [Gilleard W, McConnell J, Parsons D. The effect of patellar taping on the onset of vastus medialis obliquus and vastus lateralis muscle activity in persons with patellofemoral pain. *Phys Ther.* 1998;78:25–32.]

Key Words: *Electromyography, Patellofemoral pain syndrome, Quadriceps femoris muscle.*

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Persons with patellofemoral pain syndrome (PFPS) may have problems with the patella entering the trochlea of the femur, particularly in the first 30 degrees of knee flexion.[1] Altered soft tissue structures are thought to result in a lateral tracking of the patella.[1,2] The lateral displacement of the patella may be due to inadequate medial control from the vastus medialis obliquus muscle (VMO). This inadequate control could be due to a reduction in the tension-producing capacity of the VMO[2] or a problem with the timing of VMO activity in persons with PFPS.[3] Altered onset of muscle activity may be of particular importance to the VMO, which has a smaller cross-sectional area than the vastus lateralis muscle (VL),[4] and apparently needs time to develop force to optimally track the patella.[5]

Individuals with PFPS have been shown during some tasks to have different patterns of electromyographic (EMG) activity of the VMO relative to the VL than those found in persons without PFPS.[3,6] There is, however, some controversy because other researchers[7,8] have reported no difference in the timing of EMG activity between persons with PFPS and persons without PFPS. These different findings may be due to the different methods used to collect and analyze the data, the activity studied,[7] and the method of determining the onset of EMG activity.[3,8–12] Little consensus exists, however, regarding the most appropriate method for determining the onset of EMG activity.[11]

The lack of consensus may be due to problems with the reliability of the data in the studies. Reliability of the data demonstrates the consistency of the data and enables decisions to be made based on the data.[13] Reliability of measurements of knee joint angles during a movement task is affected by consistency of the movement from trial to trial and from day to day, as well as by the measurement equipment used and the technique used by the person taking the measurements. In addition, reliability of measurements of muscle activity is affected by the consistency of motor patterns on subsequent trials and days.[11] Mean intertrial differences[14] and intersubject correlations[15] for the kinematics of stair ascent and descent have been reported. The reliability of measurements obtained for the timing of EMG activity of selected quadriceps femoris muscles during stair ascent and descent over two test sessions has not been examined. In addition, the reliability of measurements of muscle activity during a locomotor task has been infrequently reported, and differences in muscle timing from different strides are generally not examined.[16] The error related to differences in the timing of muscle activity from stride to stride has been reported to be 3% to 6%.[16]

Physical therapists sometimes use taping of the patellofemoral joint as a treatment for patients with PFPS.[17] Some authors contend that this approach has been useful in managing patellofemoral symptoms[17,18] such as pain.[19] Taping of the patellofemoral joint in persons with PFPS may affect the onset of VMO and VL activity. Altered timing of muscle activity may mean that the muscle will be at a different length at contraction initiation, which will affect the muscle's ability to produce force.[20] Altered timing of VMO and VL activity may also affect the way in which the patella tracks in the trochlea of the femur.

Changes in the level of pain may also affect the timing of muscle activity.[21] Pain reduction may affect the kinematics of a task, which in turn may affect the timing of muscle activity. Therefore, to determine the effect of taping on the onset of muscle activity, the possible confounding effect of pain on the kinematics of a task needs to be investigated.

The onset of muscle activity in persons with PFPS has been investigated during activities ranging from tendon taps[3,7] to functional tasks such as stair climbing and walking.[8] However, the effect of patellar taping on the onset of muscle activity in persons with PFPS during functional tasks such as stair climbing, which is reported to exacerbate the symptoms of patellofemoral pain,[22] has not been reported. The aim of our study was to examine whether taping the patellofemoral joint in individuals with PFPS changed the timing of activity of

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selected quadriceps femoris muscles during walking up and down stairs.

Method

Subjects

Fourteen women with PFPS were included in the primary study after being screened for exclusion criteria. The subjects had a mean age of 22.7 years (SD=3.0, range=18–28), a mean height of 161 cm (SD=7.8, range=148–176), and a mean weight of 57.6 kg (SD=11.1, range=43–80). Informed consent was given by each subject before participation in the study, and all rights of the subjects were protected.

Procedure

Each subject was diagnosed by a physical therapist as having PFPS for which she had not previously been treated. The diagnostic criteria for PFPS were those described by Fulkerson and Hungerford.[1] The subjects' painful knees were taped[17] so that their symptoms were reduced immediately by at least 50%, as rated by the subjects during a one-leg squat pain provocation test. Subjects were excluded if they had had any knee surgery. To reduce the possible confounding effect of pain during the activity, subjects were also excluded if they experienced pain that visibly altered their kinematics when they walked up and down stairs or if they reported difficulty in walking up and down stairs without patellar taping.

Surface EMG data were collected from the thigh on the painful lower extremity. Prior to electrode application, the skin was prepared by shaving, wiping with alcohol, and abrading. Medi-trace silver-silver chloride surface electrodes* were applied in a bipolar arrangement, with a 22-mm interelectrode distance, and remained in situ throughout the test session. The electrode sites were: (1) VMO, 4 cm superior to and 3 cm medial to the superomedial border of the patella and orientated 55 degrees to the vertical, (2) VL, 10 cm superior to and 6 to 8 cm lateral to the base of the patella and orientated 15 degrees to the vertical, (3) rectus femoris muscle (RF), midway between a line drawn between the base of the patella and the anterior superior iliac spine and orientated on the same line, and (4) vastus medialis longus muscle, 10 cm superior to and 6 to 8 cm medial to the base of the patella and orientated 15 degrees to the vertical.[23] A reference electrode was placed below the tibial tubercle. All marker electrode placements were done by the same researcher. The electrodes were attached to the remote unit of a Noraxon Telemyo 8 telemetered EMG system† that was worn by the subject. The signal was then telemetered to a base unit where the signal was filtered (bandwidth=10–500 Hz) and suitably amplified to allow on-screen monitoring. The output from the amplifier was sampled at 900 Hz.

We used a random crossover design in which subjects were tested in two experimental conditions. One condition involved stepping up and down two stairs (height=20 cm) with the painful knee taped in such a way that the level of pain on a one-leg squat pain provocation test[17] was reduced at least 50%. The other condition, which served as a control, involved stepping up and down the stairs with no tape applied.

Reflective markers were applied to the greater trochanter, to the lateral epicondyle of the knee, 40 mm below the head of the fibula, and to the lateral malleolus of the affected lower limb of each subject. Data were recorded using a single video camera placed 7 m from the center of the stair apparatus and perpendicular to the plane of the movement. The video camera signal was transmitted via cable to an ExpertVision Motion Analysis System™‡ and sampled at 60 Hz.

Footswitches placed under the calcaneus and the head of the first metatarsal of each subject were used to determine when there was foot contact. Each footswitch was attached via cable to the remote unit of the telemetered EMG system. The footswitch data then were telemetered to the base unit, where the data were amplified and stored.

Prior to starting data collection, subjects were allowed enough practice trials to ensure that they could successfully place their tested limb on the first step in a normal manner and walk at the set pace. Following the practice trials, an data for an initial trial were collected for 5 seconds while each subject was standing still, facing the direction of movement. The subject then completed five trials of stepping up and down the stairs at a rate of 96 steps per minute as set by a metronome. Next, the subject was prepared for the remaining condition and was allowed enough practice trials to be comfortable with the task. The subject then completed an initial quiet standing trial for this condition, followed by an additional five trials of stepping up and down the stairs. Electromyographic, motion analysis, and footswitch data were collected.

Data Analysis

All EMG signals were full-wave rectified, smoothed, and low-pass filtered with a cutoff frequency of 3 Hz. The

* Graphics Controls Corp, subsidiary of Miller Graphic Controls Pty Ltd, 20 Kendall St, Harris Park, New South Wales, Australia 2150.

† Glonner Electronics GmbH, Faunhoferstr, 11a D-8033, Martinsried, Germany.

‡ Motion Analysis Corp, 3617 Westwind Blvd, Santa Rosa, CA 95403.

onset of muscle activity was defined as the time when the EMG signal exceeded the mean resting EMG signal (obtained at the beginning of each trial) by more than three standard deviations for a duration greater than 30 milliseconds.[9] The frame number in which the muscle was considered to be active was recorded.

A schematic representation of a thigh and shank segment was generated using videotaped data by connecting the marker representing the greater trochanter with the marker on the lateral femoral epicondyle and by connecting the marker 40 mm below the head of the fibula with the marker on the lateral malleolus. Knee angle data were obtained for each trial by calculating the angle of the shank segment with respect to the thigh segment. For each subject, the knee angle over time was calculated for each initial (quiet standing) trial. This angle was then subtracted from the knee angle data for the five subsequent trials for that condition, so that the knee joint position during quiet standing was taken as zero degrees. The frame numbers for EMG onset times were then compared with the same frame numbers for knee angle data to yield the knee angle at the onset of activity for each muscle.

We believe that patellar taping may have resulted in variations in step-up or step-down times, regardless of the external timing provided by the metronome. Therefore, each trial was displayed and the on and off times of the footswitch were determined visually and recorded. The use of footswitches provided information regarding the swing and stance phases of walking up and down stairs and allowed the calculation of step-up and step-down times. Times taken for the step-up and step-down tasks were obtained from the footswitch data by calculating the time taken between heel-strikes.

We were concerned that the application of tape and consequent skin gathering might cause an alteration in the EMG signal, which may have affected our ability to detect the onset of muscle activity. We therefore investigated the proportion of the amplitude of the three-standard-deviation definition to the peak movement EMG signal amplitude.

A within-subjects, repeated-measures analysis of variance (ANOVA) with preplanned contrasts was performed on the data for knee angle at onset of muscle activity, peak flexion and extension, and temporal variables.[24] The contrasts were used to examine the step-up and step-down tasks for differences between taping conditions, knee angles at onset of muscle activity, and experimental conditions on the peak angles and step-up and step-down times. Contrasts were also used to detect any linear or quadratic trends across the trials that we believe would indicate the effect of motor learning or fatigue.[24]

The alpha level was set at .05 for all statistical analyses, and the critical F value was 4.67. The absolute probability of getting an F value of that size under the hypothesis of no difference was included for each F value. Trial-to-trial reliability for onset of VMO and VL activity for the five trials of walking up and down stairs, with and without patellar taping, for the 14 subjects with PFPS was investigated using percentage of close agreement (PCA) and intraclass correlation coefficients (ICC[3,1]).[25]

Test-retest reliability was measured with data from three subjects who had no pain. Data were obtained from four trials of walking up and down stairs, which were repeated 1 week later. Patellar taping for a medial glide[17] was used as the taping protocol. We used data from subjects without pain because it could not be assumed that the onset of muscle activity of subjects who were undergoing treatment that is thought to improve VMO activation[17] would be consistent across the testing periods. Test-retest reliability of the kinematics of the movement task and onset of EMG activity in the VL and VMO was investigated using PCA, the Pearson correlation coefficient (r), and the standard error of measurement (SEM) with a 95% confidence interval (SEM$\times$1.96).[25]

Results

Reliability

The test-retest and trial-to-trial reliability results are summarized in Tables 1 through 3. Table 1 shows that, on average, 85% of the test-retest repeat measurements of knee joint kinematics during the step-up and step-down tasks for the subjects without pain were within 5 degrees in the control condition and 75% of these measurements were within 5 degrees in the taped condition. On the basis of the SEM data, 95% of repeated peak flexion and extension measurements during the step-up and step-down tasks would be expected to be, on average, within $\pm$5.5 degrees without patellar taping and within $\pm$7 degrees with patellar taping.

The reliability of measurements of onset of EMG activity in the subjects without pain over two test occasions was 66% and 61% average PCA at 5 degrees for the taped and control conditions, respectively (Tab. 2). On the basis of the SEM data, 95% of repeated measurements of onset of EMG activity during the step-up and step-down tasks would be expected to be, on average, within $\pm$10 degrees without patellar taping and within $\pm$7 degrees with patellar taping.

The trial-to-trial reliability over five trials of the step-up and step-down tasks for the subjects with PFPS was 76% average PCA at 5 degrees in the taped condition and 70% average PCA at 5 degrees in the control condition

Table 1.
Percentage of Close Agreement (PCA) and Standard Error of Measurement (SEM) for Day-to-Day Reliability of Measurements of Peak Flexion and Extension in Subjects Without Pain (n=3)

Task	Condition[a]	PCA at 5°	*r*	SEM	95% Confidence Interval (SEM×1.96)
Step up					
Peak flexion	Control	83	.66	3.04	±6°
	Taped	83	.79	2.59	±5°
Peak extension	Control	83	.81	3.11	±6°
	Taped	83	.90	2.49	±5°
Step down					
Peak flexion	Control	83	.79	3.30	±6°
	Taped	59	.38	6.14	±12°
Peak extension	Control	92	.78	2.14	±4°
	Taped	83	.25	3.07	±6°

[a] In the taped condition, the patellofemoral joint of the right knee was taped. In the control condition, the patellofemoral joint was not taped.

Table 2.
Percentage of Close Agreement (PCA) and Standard Error of Measurement (SEM) for Day-to-Day Reliability of Measurements Obtained for Onset of Muscle Activity in Subjects Without Pain (n=3)

Task	Condition[c]	PCA at 5°	*r*	SEM	95% Confidence Interval (SEM×1.96)
Step up					
VMO[a]	Control	67	.36	4.11	±8°
	Taped	58	.79	2.04	±4°
VL[b]	Control	75	.40	3.71	±7°
	Taped	75	.66	3.79	±7°
Step down					
VMO	Control	67	.84	4.14	±8°
	Taped	64	.84	5.05	±8°
VL	Control	36	.69	9.01	±18°
	Taped	67	.95	3.54	±7°

[a] VMO=vastus medialis obliquus muscle.
[b] VL=vastus lateralis muscle.
[c] In the taped condition, the patellofemoral joint of the right knee was taped. In the control condition, the patellofemoral joint was not taped.

(Tab. 3). The average ICC(3,1) calculation for the taped and control conditions was .783 and .776, respectively.

Onset of Muscle Activity

When walking up stairs, the knee joint moves from a relatively flexed position to a more extended position as the body is displaced vertically up the stairs. The mean knee angles at the onset of muscle activity during the step-up task in the control condition ($\bar{X}$=71.43°, SD=.19°, range=49°–93°) and in the taped condition ($\bar{X}$=75.71°, SD=0.89°, range=57°–94°) show that the onset of VMO activity occurred earlier in the movement when the patellofemoral joint was taped compared with the control condition (F=18.657; *df*=1,13; *P*=.0008). There was no effect, however, of taping on the onset of VL activity during the step-up task (F=0.014; *df*=1,13; *P*=.9076). When comparing the onset of muscle activity between the VL and the VMO during the control condition, the VL did not activate earlier than the VMO (72.71° versus 71.43°) (F=0.568; *df*=1,13; *P*=.0465). With patellofemoral taping, however, the VMO activated earlier than VL (75.71° versus 72.54°) (F=10.907; *df*=1,13; *P*=.0057) during the step-up task. There was no effect of taping on the onset of VML and RF activity during the step-up task.

When walking down stairs, the knee joint moves from a relatively extended position to a more flexed position as the body is displaced vertically down the stairs. The mean knee angles during the step-down task in the control condition ($\bar{X}$=31.90°, SD=1.30°, range=16°–59°) and in the taped condition ($\bar{X}$=29.64°, SD=1.28°, range=12°–42°) show that the onset of VMO activity occurred earlier in the movement when the patellofemoral joint was taped compared with the control condition (F=5.751; *df*=1,13; *P*=.0321). Interestingly, the onset

Table 3.
Percentage of Close Agreement (PCA) and Intraclass Correlation Coefficients (ICC[3,1]) for Trial-to-Trial Reliability of Measurements Obtained for Onset of Muscle Activity in Subjects With Patellofemoral Pain Syndrome (n=14)

Task	Condition[c]	PCA at 5°	ICC
Step up			
VMO[a]	Control	68	.858
	Taped	84	.898
VL[b]	Control	81	.890
	Taped	95	.899
Step down			
VMO	Control	65	.678
	Taped	65	.717
VL	Control	67	.747
	Taped	59	.623

[a] VMO=vastus medialis obliquus muscle.
[b] VL=vastus lateralis muscle.
[c] In the taped condition, the patellofemoral joint of the painful lower extremity was taped. In the control condition, the patellofemoral joint was not taped.

of VL activity was delayed from 30.93 degrees (SD=1.98°, range=20°–56°) in the control condition to 36.77 degrees (SD=1.65°, range=22°–57°) in the taped condition (F=15.144; df=1,13; P=.0019).

In the control condition, the VMO did not activate earlier than the VL (31.90° versus 30.93°) (F=0.383; df=1,13; P=.05467). In the taped condition, however, the VMO activated earlier than VL (29.64° versus 36.77°) (F=13.043; df=1,13; P=.0032). Data for onset of VML and RF activity during the step-up task were unavailable because these muscles remained active throughout the activity.

We did not believe that these results were related to EMG signal degradation. The proportion of the amplitude of the three standard deviation definition to the peak movement EMG signal amplitude did not exceed 8% in the control condition or 9% in the taped condition. We therefore assumed that the effect of skin gathering on detection of true onset of muscle activity was minimal.

For each subject, there was no indication of muscular fatigue or a learning effect over all trials. There was also no difference in the time to complete the step-up or step-down task or in peak knee flexion and extension between taping conditions.

Discussion

Reliability

We investigated the reliability of kinematic measurements obtained during step-up and step-down tasks as well as the reliability of measurements of onset of muscle activity during these tasks. The test-retest reliability of kinematic measurements in the control condition revealed that 85% of the measurements were within 5 degrees and had a 95% confidence interval of ±5.5 degrees, which reflects the degree of variation in the tasks. Although test-retest reliability for kinematic measurements during step-up and step-down tasks has not previously been reported, trial-to-trial mean differences of less than 1 degree have been reported by Jevsevar et al,[14] with standard deviations indicating variations of about ±4 degrees. The test-retest reliability for kinematic measurements in persons with PFPS is unknown.

Onset of muscle activity across taping conditions for the step-up and step-down tasks in our study was within 5 degrees, on average, 63.5% of the time for the subjects without pain from test to retest and 73% of the time for the subjects with PFPS from trial to trial. Trial-to-trial variability in onset of muscle activity during walking was also reported by Bogey et al,[16] although the differences were not documented. In calculating a control group mean onset time, these investigators regarded trials in which the onset varied by more than two standard deviations from the mean as outliers. These outliers were removed from further calculations.[16] No justification, however, was given for this exclusion, and the number of exclusions was not reported. The level of normal variation present, both between trials and from test to retest, in onset of muscle activity for locomotor tasks is not clear from the literature.

Knee Angle and Electromyographic Activity in the Control Condition

The results of this study did not reveal a timing delay of activity of the VMO relative to the VL in the subjects with PFPS, supporting the findings of Karst and Willett[7] and Powers et al.[8] A timing delay has been found in other studies of individuals with patellofemoral pain in which the reflex response time of the VMO and the VL following a patellar tendon tap was investigated.[3,12] We were concerned only with the activities of walking up and down stairs, so we cannot compare our data with the response times from the patellar tendon taps because onset time differences have been reported to be task specific.[7] Where identical task protocols are used, the onset of EMG activity is likely to be dependent on the computer algorithm used.[11] Differences in EMG detection protocols may have led to the discrepancies in the reported results.

Effect of Taping on Knee Angle and Electromyographic Activity

As we anticipated, patellar taping had no effect on the onset of VML and RF activity because the line of action of both muscles is generally parallel to the femur and should be unaffected by taping the patellofemoral joint in a mediolateral direction. Our results, however, show that patellar taping in persons with patellofemoral pain affects the onset of VMO and VL activity during step-up and step-down tasks. We could not determine whether the altered timing is the result of pain reduction or altered mechanics, which may affect the neurological control of the muscle.

We believe that the earlier activation of the VMO and the delayed activation of the VL that we observed should allow for a more optimal positioning of the patella into the trochlea, particularly if there are factors (eg, a tight lateral retinaculum) that could be contributing to the poor positioning of the patella. Fulkerson and Hungerford[1] reported that patellofemoral pain often seems to be associated with abnormal patellar tracking during the first 30 degrees of flexion. Patellar instability beyond 30 degrees of knee flexion is relatively uncommon,[1] but the contact area of the patella on the femoral condyles may be altered if an individual has abnormal mechanics. We believe that the earlier activation of the VMO and the delayed activation of the VL during the step-down task may help to improve the timing of force distribution and decrease the pressure placed on a particular portion of the articular cartilage. It is unknown whether a small change in the onset of muscle activity affects the pressure distribution or whether changes in joint contact area, possibly as a direct consequence of taping, affect the onset of muscle activity.

The change in onset of muscle activity may change the relative excitation of the VMO and VL. Grabiner et al[5] postulated that the VMO needs time to develop force, relative to the VL, to optimally track the patella. There is a tendency for the patella to track laterally, particularly because the VL has a larger cross-sectional area than the VMO.[4] The change in timing of onset of muscle activity to achieve this effect is unknown.

The mechanisms by which patellar taping may result in altered onset of muscle activity are unknown. The VMO may be activated earlier due to a cutaneous stimulation effected by the tape. Researchers[26,27] have demonstrated that cutaneous stimulation alters the recruitment threshold and recruitment order of motor units, although the precise mechanism by which this occurs is unclear. The taping procedure may also change the patella position.

Conclusion

Some people believe that patellar taping should be used in the management of patellofemoral pain. Our data show that taping the patellofemoral joint changes the onset timing of VMO and VL activity. The earlier activation of the VMO may promote VMO activity during retraining, improving patellar tracking.

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