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Effects of rehabilitative exercises on iEMG activity of Vastus Medialis Oblique and Vastus Lateralis

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Abstract

Patellofemoral pain syndrome (PFPS), known as anterior or retropatellar pain, is reported to be the prime cause of knee pain. One of the main reasons of PFPS is abnormal tracking of the patella within the femoral trochlea. Abnormal tracking may be due to a delayed onset of the vastus medialis oblique (VMO) relative to vastus lateralis (VL). The aim of this study is to investigate the effects of selected rehabilitation exercises on integrated electromyography (iEMG) activations of VMO and VL. Electromyography (EMG) is a commonly used tool capable of providing information regarding muscle activation during rehabilitative exercises. Ten male subjects, age range 18-37 years, without PFPS participated in this study. Subjects performed four rehabilitative exercises in Industrial Kinesiology Lab (DEI): (1) straight leg raise with neutral hip position (SLRN), (2) straight leg raise with externally rotated hip position (SLRER), (3) medial (internal) tibial rotation (MTR) and (4) hip adduction (HA). One way ANOVA with repeated measures indicated that there was no significant difference in VMO/VL ratio across the selected rehabilitative exercises. The highest iEMG activation in VMO and VL was observed in hip adduction (HA). MTR produced higher iEMG activation in comparison to straight leg raise in supine positions. Hip adduction and MTR exercises, therefore, may be advisable in the treatment of patients with PFPS with accompanying pain or instability.

Keywords: patellofemoral pain syndrome, rehabilitative exercises, electromyography, vastus medialis oblique, vastus lateralis

Introduction

Patellofemoral pain syndrome (PFPS) is common in the general population. It prevalence has been estimated as high as 25% (Hung and Gross, 1999; Laparde, 1998). PFPS symptoms are diffuse pain, patellofemoral joint crepitus, peripatellar swelling and locking of knee. PFPS is aggravated by occupational activities involving prolonged sitting, climbing stairs, squatting and kneeling (Cowan et al., 2003). As a consequence, both surgical and conservative treatments to correct this malalignment have been suggested. The study of the muscles from this perspective can provide valuable information concerning the control of the voluntary and reflexive movements. The study of muscles activity during a particular task can yield insight into which muscles are active when the muscle initiate and cease their activity (Hamill and Knutzen, 2009). Electromyography (EMG) is a commonly used tool capable of providing information regarding muscle activation during rehabilitative exercises. Many clinicians focus their treatment of PFPS on restoring the strength of the VMO in order to increase the VMO/VL ratio, and also on improving the timing of the VMO and VL contractions in order for them to occur simultaneously. To selectively strengthen the VMO, one must perform exercises in which the VMO is significantly active in comparison to the other muscles of the leg. Because of its lateral pull on the patella, the activity of the vastus lateralis muscle (VL) is often compared with the activity of the VMO (Moller et al., 1986). VMO muscle's role in knee rehabilitation was evaluated and it was found that none of the rehabilitation methods consistently resulted in preferential VMO activation during various lower extremity exercises (Westfall and Worrell, 1992). Livecchi et al. (2002) investigated the VMO/VL value during straight leg raise with neutral hip position (SLRN) and straight leg raise with externally rotated hip positions (SLRER). No differences in VMO/VL ratio were found. Roush et al. (2000) carried out a study across these two exercises in support of SLRER for rehabilitation of anterior knee pain, finding improved patient outcomes and cost effectiveness. Another EMG study demonstrated that hip adduction (HA) produced higher action potentials in VMO possibly "due to the inertia of the leg" (Wheatley and Jahnke, 1951). Reynolds et al. (1983) also laid down the addition of adduction while performing knee extension exercises might facilitate the VMO. SLRN and SLRER, medial (internal) tibial rotation (MTR) and HA have not been extensively evaluated relative to their effects on the VMO and VL muscles. Therefore, in this study we aim to determine whether the EMG activity of VMO differs significantly from that of VL during selected rehabilitative exercises.

Materials and methods

Experiments were performed on 10 male workers age range 18-37 years, without patellofemoral pain syndrome. Subject's name, age in years, work experience in years, height in centimeters, and weight in Kilograms are recorded. Body mass index is calculated for each subject (Table 1).

Table 1: Demographic data.

Subjects	Age	Weight	Height	BMI
	(yrs ± SD)	(Kg ± SD)	(cm ± SD)	(Kg/m^2 ± SD)
10	30.7 ± 4.8	66.9 ± 7.7	168.1 ± 4.8	23.63 ± 2.2

Subjects are given a brief explanation of the EMG equipment along with a demonstration of four selected rehabilitative exercises. In the supine positioned exercises, 2.2 kgs weight was used at the heel upper side (bound with tape) and in the hip adduction and MTR exercises, each subject was told to apply maximum force at the end of each movement. Informed consent was obtained from each subject prior to each test. Subjects performed four rehabilitative exercises (Figures 1- 4) in Industrial Kinesiology Lab. (DEI): (1) Straight leg raise with neutral hip position (SLRN), (2) Straight leg raise with externally rotated hip position (SLRER), (3) Medial (internal) tibial rotation (MTR) and (4) Hip adduction (HA). Surface iEMG was used to analyze the motor recruitment of the vastus medialis oblique (VMO) and vastus lateralis (VL) muscles.

Equipment and instruments

The Biopac Tel-100 EMG system (Biopac Systems, Inc. 2007, Goleta, CA) was used to measure muscle activity of each subject. The EMG data were analyzed using Acknowledge software. Bipolar adhesive surface electrodes (Ag - AgCl) are used over the muscle bellies of the VMO and VL.

Fig. 1: SLRN.

Fig. 2: SLRER.

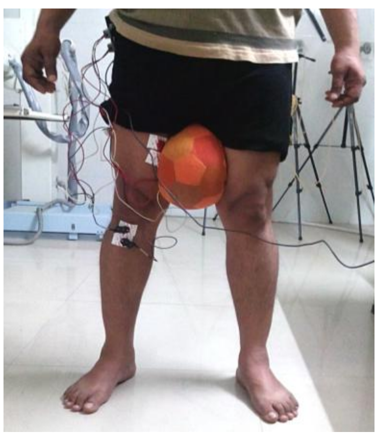

Fig. 3: MTR.

Room temperature was about 30 degree centigrade. Each subject was prepared for electrode placement. The dominant leg, as determined by handedness of the subject, was used for all subjects for electrode placement by shaving the designated areas to remove hair and dead skin cells. Then, the areas were abraded using a coarse pad and rubbed clean with spirit and towel. The electrodes were placed parallel to the direction of the muscle fibers on the VMO and VL. According to Zipp, (1982), the fibers of the VMO run at approximately a 55 degree angle medial to the quadriceps tendon, and the electrode was placed 20% of the distance from the medial joint line of the knee to the anterior superior iliac spine. The fibers of the VL are at 12 degree to 15 degree lateral to the quadriceps tendon. The electrodes were placed at the midpoint between the head of the greater trochanter and the lateral femoral epicondyle. Ground electrodes were placed on 6 to 8 cm from the inferior pole of the patella along the bony shaft of the anterior tibia (cushion et al, 2012).

Fig. 4: HA.

During each repetition of all the exercises, a designated researcher marked the concentric and eccentric phases using the computer keyboard to mark phase repetition. Subjects were allowed a three minute recovery period in between each exercise. The EMG data were sampled at 1,000 Hz and amplified 2,000 times by the Tel-100 unit. The peak value of the iEMG data for each muscle was used to normalize.

Data analysis

iEMG differences among the exercises were tested for statistical significance using one-way analysis of variance (ANOVA) with an alpha level of 0.05 for each muscle. If significance was found using one-way ANOVA, post hoc analysis using least significant difference (LSD) test was performed to compare exercises using $P < 0.05$ for the level of significance. Means and standard deviations were computed for the normalized EMG readings of the VMO and the VL for all the exercises.

Results

One way ANOVA with repeated measures indicated that there was no significant difference in VMO/VL ratio across the selected rehabilitative exercises.

Means and standard deviations of the normalized EMG values for the VMO and VL during SLRN, SLRER, HA and MTR are listed in the Table 2. The results of the post hoc comparisons revealed that a significant difference existed between the group means of the VMO and the VL with the motion of hip adduction ($P < 0.05$). The difference noted between the means of the VMO and VL with the motion of medial tibial rotation was not significant.

Table 2: iEMG (% MVC ± SD) value of VMO and VL for four selected rehabilitative exercises.

Exercises	VMO	VL	VMO/VL
SLRN	45.11±14.7	41.51±13.1	1.17±0.5
SLRER	44.95±14.2	38.54±12.8	1.23±0.42
MTR	66.56±20.2	51.47±9.9	1.3±0.37
HA	81.97±23.7	83.71±21.4	0.98±0.17

Table 3 demonstrates the exercises producing significantly higher iEMG value ($iEMG_{high}$).

Table 3: Exercise producing significantly higher iEMG value for VMO and VL.

Muscles	Exercise Producing $iEMG_{high}$	$iEMG_{high}$ is significantly higher than from EMG of
Vastus Medialis Oblique	HA and MTR	SLRER and SLRN
Vastus Lateralis	HA	SLRER and SLRN
	HA	MTR

Discussion

iEMG activations of MTR and HA were significantly greater than SLRN and SLRER for VMO and VL. Hip adduction exercise and medial tibial rotation exercises, therefore, may be advisable in the treatment of patients with PFPS with accompanying pain or instability.

Hip adduction exercise serves two functions in the rehabilitation of patients with PFPS. First by strengthening the VMO, HA reduces the lateral pull on the patella. Second, it is considered that strong hip adductors give the VMO stable origin.

To provide a homogeneous population for our protocol, healthy subjects were studied. The result of this study shows that hip adduction significantly increases the activations of the VMO when compared with the VL. We found normalized iEMG readings of 81.97 % and 83.71% for the VMO and VL, respectively (Table 2). Hip adduction has been supported by some researchers as a means of selectively strengthening the VMO. Surface electrodes are more sensitive than simulation reading collected with the underlying fine–wire electrodes. We used surface electrode in order to ensure that our collected EMG reading were specific to the VMO and VL.

The results of the study also showed that MTR would significantly increase the activations of the VMO when compared with the VL. We found normalized iEMG readings of HA as 66.56% and 51.47% for the VMO and VL, respectively (Table 2).

The effect of simultaneous knee extension and hip adduction on electrical activity of VMO and VL was also studied (Andriacchi et al., 1984). The results of this study showed a decrease in the activations of VMO and VL, which may be attributed to the followings facts: (1) submaximal values are tested, (2) sample size is small, and (3) the abduction torque was applied to the lower leg.

Researchers have experimented with medial tibial rotation exercise to strengthen VMO selectively (Engle, 1987; Hanten and schulthles, 1990). Engle, (1987) demonstrated that MTR produced higher activations in VMO when knee was in slight extension. Hanten and schulthles, (1990) tested MTR at 30 degrees of flexion and concluded that VMO can not be selectively strengthened. However the results of the present study show that iEMG activations of VMO are significantly higher than that of VL although the subjects performed MTR with no resistance. Also surface electrodes are used in the present study to record iEMG signals, whereas wire electrodes were used in the study by Hanten and schulthles, (1990).

VMO is selectively strengthened to reduce the lateral malalignment of the patella, whereas VL must have significantly less activations (Moller et al, 1986, 1986; Maquet, 1984). It has been demonstrated by many studies that VMO is not selectively strengthened during knee extension exercise. VMO/VL ratio is not found significantly different across four rehabilitative exercises in the present study (i.e., SLRN, SLRER, MTR and HA). It varied from 0.98 to 1.3.

In the present study we adhered to the standard norms pertaining to procedures of recording EMG signals. We used same day recording to reduce variability in the results (Knutson et al., 1984). Bipolar placement of electrodes has been used to minimize crosstalk interference (Sykes et al., 2003; Zipp, 1982; Pincivero et al., 2003)

Conclusion

Results demonstrate that VMO/VL ratio was not statistically significant across all the four exercises. However for MTR, iEMG activity of VMO was found significantly higher than that of VL. The highest iEMG activation in VMO and VL was observed in hip adduction (HA) among all exercises. This outcome is supported by Hanten and Schulthies, (1990), who compared two exercises HA and MTR. iEMG activatity of MTR was significantly greater than that of SLRN for VMO and VL. Whereas iEMG activity of HA was significantly greater than that of SLRN and SLRER for VMO and VL. HA was significantly greater than MTR for VL. Hip adduction and MTR exercises, therefore, may be advisable in the treatment of patients with PFPS with accompanying pain or instability.

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Conflict of interest: None.

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