An Electromyographic Comparison of Vastus Medialis Oblique and Vastus Lateralis Ratios in Open and Closed Chain Exercises

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ABSTRACT

Patellofemoral pain syndrome (PFPS) has been reported as the number one cause of knee pain in the United States. Muscle imbalances between the vastus lateralis (VL) and vastus medialis (VMO) can cause a lateral tracking problem for the patella. According to a study by Hung & Gross (1999), strengthening of the VMO can reduce this pattern. Previous research has conflicting results as to the success of VMO isolation. Success has been found by combining movements and positions of the lower extremity. This study examined both lower extremities of 15 healthy adults by combining closed-chain knee extension with medial tibial rotation and hip adduction (KEMRAD) then compared the electromyographic (EMG) activity to that of typical quadriceps setting. Paired, two-tailed, t-test analysis revealed statistical significance in VMO/VL ratios between the two exercises. The conclusion is that the combination of knee extension, medial tibial rotation, and hip adduction results in selective recruitment of the vastus medialis oblique.
Key Words: Knee Exercise, Quadriceps, Electromyography.

INTRODUCTION

The term Patellofemoral pain syndrome (PFPS) is used to describe a number of conditions associated with Patellofemoral joint dysfunction[5]. Patellofemoral pain syndrome is commonly diagnosed and is one of the most commonly seen knee problems in orthopedic practice[4]. It is therefore important to understand the proper treatment and prevention techniques regarding the dysfunction.

Lateral movement of the patella has been suggested as a major cause of PFPS[1]. The inferior portion of the vastus medialis (VM) muscle has fibers oriented obliquely; this portion of the VM is the primary muscle contributor to the overall medial force vector to the patella[4]. The vastus lateralis muscle provides a strong lateral force to the patella, and has been found to have a greater cross sectional area as well as a higher percentage of high threshold fibers[10]. If the vastus medialis oblique (VMO) atrophies, it is believed that greater lateral deviation of the patella will occur, thus contributing to abnormal joint stress and PFPS[6].

In a study of six normal cadaveric lower limbs, Goh and Lee (1995)[2] studied the effect of the VMO on the Patellofemoral joint. They found that absence of VMO tension resulted in a lateral displacement of the patella and increased load on the lateral patellar facet throughout the range of knee motion.

The VMO originates from the adductor longus and magnus tendons and the medial intramuscular septum, with the majority of fibers arising from the tendon of the adductor magnus[6]. Based on this, Monteiro-Pedro et al., (1998)[8] suggest that activation of the knee extensors and hip adductors might provide the

VMO with a more stable base for contraction and so increase intensity of contraction. They recorded the EMG activity of the VMO during free isotonic and maximal isometric contraction of the knee extensors combined with hip adductors in sitting and side lying. The results showed that activity of the VMO was significantly greater in both exercises of maximal contraction as compared to free isotonic contraction in side lying. However, there was no difference between the two exercises in sitting. Their findings suggest that the exercises of hip adduction with knee extension could be performed in sitting either isotonically or isometrically.

The lower most fibers of the VMO insert on the anteromedial aspect of the tibia through the extensor aponeurosis and may act to resist external rotation of the tibia. Hung & Gross examined the effect of foot position on VMO activity using two exercises: maximal isometric quadriceps contraction with the knee extended and single leg short squats with a knee flexion ROM 0-50^o . The subjects performed the exercises in three foot positions: level surface, 10^o medial wedge, and 10^o lateral wedge. They found that the ratio of VMO/VL contraction was significantly greater during the short squat than maximum isometric contraction. Hey found no difference, however, between the three foot positions.

Laprade et al., (1998)[6] studied the EMG activity of the VMO in relation to the VL during five isometric exercises in PFPS subjects and controls. The exercises they used were: hip adduction; adduction with knee extension; medial tibial rotation; knee extension; and knee extension with medial tibial rotation. Their data was normalized as VMO: VL ratio. The results showed significantly greater VMO/ VL ratios for knee extension combined with medial tibial rotation as well as for knee extension alone over the other isometric exercises.

Cerny (1995)[1] examined different exercises and the effects of hip/knee rotation position on the VMO to VL ratio. Taping of the patella was also studied to determine any effect on the VMO. EMG activity of VMO, VL, adductor magnus muscle, and VMO/VL ratio was measured. The results of her study showed significance in VMO/VL ratio in knee extension with medial rotation. No difference in VMO activity was found due to patellar taping.

Sheehy et al., (1998)[9] examined the EMG activation of the VMO and VL during ascending and descending stairs. Peak VMO/VL ratios of EMG activity and differences in VMO and VL onset times were measured. No significant difference was found in onset timing or peak muscle activity. However, significant difference was found in the concentric phase while ascending and eccentric phase while descending steps. This suggests greater VMO activity with lower limb weight bearing.

The results of a study by Mirzabeigi et al., (1999)[7] sugest that the VMO cannot be isolated during the examined exercises. They selectively challenged the VMO in comparison with the VL, VI, and VM muscles by performing nine sets of strengthening exercises. They found the exercises to challenge both the VMO and VL without difference. The data in this study was not shown as a ratio of VMO/VL activity. The larger cross-sectional area of the VL muscle could account for their finding of equal activation of both muscles.

Zakaria, Harburn, & Kramer (1997)[11] investigated whether the VMO, VL, and hip adductor muscles could be preferentially activated during three exercises. They found no significant preferential activation of the components of the quadriceps femoris. They also found that use of the hip adduction to activate the VMO over the VL was not substantiated. The exercises studied in this experiment used quad sets and a pure form of hip adduction. These exercises are nonfunctional in nature, and the use of more functional exercises may yield contrasting results regarding VMO/VL activation.

Other research findings suggest that a fault in the firing sequence of the VMO and VL could be the major contributor to PFPS. Witvrouw et al., (1996)[10] investigated reflex response times of the VMO and VL after a patellar tendon tap. They compared results of healthy and PFPS patients in terms of firing order and reflex response time. Their results suggest that a reversal has occurred in the firing pattern of the VMO and VL in PFPS patients. The results suggest that there is a neuromuscular component involved in patellofemoral pain syndrome.

The current research is conflicting in the isolation and role of the VMO in PFPS. Most studies agree that the VMO plays an important role in PFPS however there is conflicting data as to the ability to isolate the VMO from the VL with exercise.

The purpose of the present study was to attempt to find significant difference in VMO: VL ratios by comparing closed chain knee extension with medial tibial rotation and hip adduction with quadriceps setting. This will combine the positive positions and movements associated with increased VMO: VL ratios from the previous research.

MATERIALS AND METHODS

Subjects

The first fifteen subjects (age 18 or older) meeting the admitting criteria, regardless of gender, were used for the study. Subjects were volunteers from Piedmont Therapy and Hart Industrial Clinic. There were 9 females and 6 males, all Caucasian, used in the study. Admitting criteria were no prior history of patellofemoral joint dysfunction or other knee problems. One male subject was excluded from the study due to a leg length discrepancy that would have interfered with his standing bare foot. All subjects signed an informed consent form approved by Winston-Salem State University prior to participation.

Equipment

A Pathway™ MR-20, Dual Channel, Surface EMG device was used to measure EMG activity. Data was recorded with Pathway™ Utilities/Compliance Software program version 1.60. Surface electrodes were Franklin®, Soft Strike™ 7 soccer ball, purchased at a local toy store, was used between the subject's legs for support during adduction. A three-inch towel roll was used under the knee during the quadriceps setting. Tape-lines were placed at 30^{o} external rotation for each foot, measured at 10 inched apart.

Procedure

Testing took place at Hart Industrial Clinic and Piedmont Therapy in Hickory, North Carolina. The subjects reported for testing in gym shorts and a t-shirt, which allowed access to anatomic landmarks for the placement of electrodes. Qualified subjects were instructed how to perform the two exercises in the following way: Quadriceps set will be performed while sitting on the plinth, with your knee fully extended you should tighten your leg muscles by trying to push your knee into the towel roll and hold it for 5 seconds; KEMRAD exercise will be performed while standing with your toes pointing towards and the ball between your knees. As you squeeze the ball between your knees, slowly, for a total duration of 5 seconds, you will lower yourself in a squat position till you are signaled by the researcher to slowly return standing upright. EMG activity was measured for both exercises on both lower extremities.

Electrode Placement

The skin was prepped with isopropyl alcohol. One electrode was placed over the muscle belly of the VMO in line with its fiber orientation; the other electrode was placed over the VL in a longitudinal orientation. The placement of the electrodes was in the area of the greatest muscle bulk, approximately 4 cm from the superomedial aspect of the patella for the VMO and 15 cm from the superolateral aspect of the patella for the VL.

Intervention: Quadriceps Setting

Each subject was positioned in long sitting on the plinth with a three-inch towel roll will be placed under the knee. The subject tightened the quadriceps muscle group, forcing the knee into the towel roll. The quadriceps set was held for 5 seconds. The data recording was begun 1 second after initiation of the exercise. The EMG data was recorded and saved to disk. See Fig. (1).

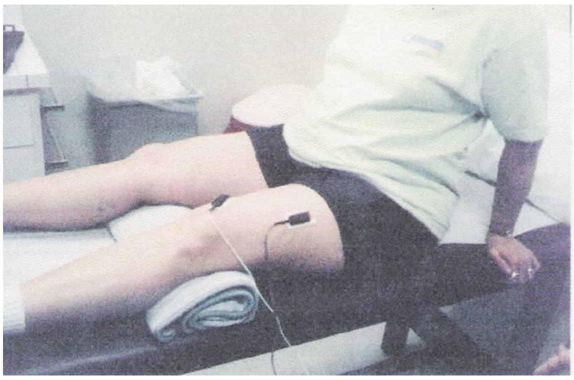

Fig. (1): Subject positioning for quad set exercises. Participant in long-sitting with towel roll tested knee.

Intervention: Knee Extension, Medial Tibal Rotation, Hip Adduction (KEMRAD)

Subjects were standing and the clinician positioned their feet with the tapeline under the second metatarsal. The ball was placed between their knees immediately below the medial femoral chondyles. The assisting researcher measured the knee flexion angle as the subject performed the squat. When the participant reached 30^o, the subject was told to return to standing. The data recording was begun 1 second after initiation of the exercise. EMG data was recorded and saved to disk. See Fig. (2).

Fig. (2): Subject performing the KEMRAD exercise with ball between knees.

Statistical Analysis

EMG signals were digitized and recorded at every 0.1 second and expressed as µV. The initial 2 seconds of each exercise were used for analysis.

Normalized EMG values of the VMO and VL for both exercises were obtained by relating the EMG output values to the maximal output of each muscle. The results were then expressed as percentages of maximal muscle output.

Normalized EMG values for the VMO and VL exercises were then expressed as ratios of VMO: VL. The mean was calculated for each exercise for both lower extremities. The mean and standard deviation of VMO: VL ratios for each exercise are shown in Table (1). The mean of VMO: VL ratios for each exercise and lower extremity are shown in Chart (1). The data for each leg was analyzed using a two-tailed t-test and the overall data was analyzed using a paired, two-tailed, t-test. Significance was defined as $P<0.05$.

Table (1): Mean and S between exercises.

	Quad set overall		KEMRAD Overall	
Exercises	Mean	SD	Mean	SD
	1.21	0.64	2.50	1.32

RESULTS

Results from a two-tailed t-test revealed a significant difference between quadriceps setting and KEMRAD exercise for both the left and right lower extremities. No significance was found between right and left lower extremities of the same exercise using a paired t-test. Significance was found between quadriceps setting and KEMRAD exercises overall using a paired, two-tailed t-test. See Table (2).

Table (2): Statistical Outcomes of VMO/VL ratio.

Compared Variables	Quad Set vs. KEMRAD Right LE	Quad set vs. KEMRAD Left LE	Right LE vs. Left LE Quad Set	Right LE vs. Left LE KEMRAD	Quad Set vs. KEMRAD Overall
P value	0.009*	0.001*	0.91	0.86	0.001*

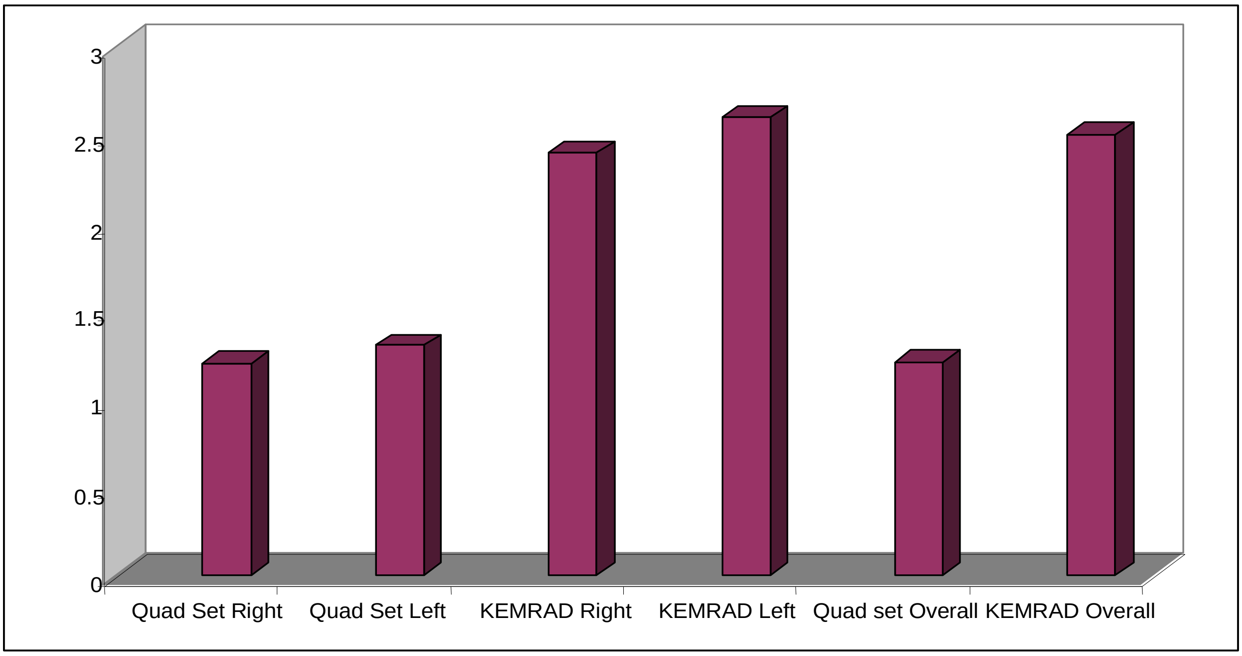

Chart (1): Mean VMO/VL ratios for each exercise.

DISCUSSION

The purpose of this study was to determine if the vastus medialis oblique muscle could be selectively challenged when comparing EMG activity with the vastus lateralis. Two different exercises were performed by 15 uninjured subjects to determine the ratio of muscle activation when comparing the VMO to the VL. This study combined muscle movements that had previously been identified as contributing to VMO activation into one exercise.

The results of this work showed that the EMG activity of the VMO muscle was significantly greater when combing knee extension with medial tibial rotation and hip adduction then with quad setting alone. It appears from the results of this study that if the goal of the clinician is to preferentially recruit or strengthen the VMO, quadriceps sets would not be effective in attaining this goal. It has been determine that isolation of the VMO requires a combination of movements based on fiber orientation and muscle attachment.

Further clinical trails are needed to determine the efficacy of combined movements in improving symptoms of PFPS. The KEMRAD exercise described in this study should be compared with the typical PFPS rehabilitation regimen, such as short arc quad strengthening and decreased weight bearing activity.

The current study is limited by the number of exercises compared. Only two exercises were compared due to time constraints and convenience. Further studies should examine VMO recruitment when comparing typical knee extension exercises. Another limitation of this study is the difficulty of the KEMRAD exercise. At least one subject reported that performing the exercise was uncomfortable. When attempting this exercise with a patient who is experiencing knee pain, the amount of weight bearing required for the KEMRAD exercise would limit its use for acute patients. This study is further limited by the subjects used. All of the participants in this study were healthy and had no past patellofemoral injuries. Different results may be found in patients with PFPS. Other limitations are the lack of racial diversity in participants: location of muscle bulk on shorter or taller than normal participants, and the comparison of an isometric exercise to an isokenetic exercise is difficult.

Conclusion

In conclusion, significant difference was found between quad set exercises and the KEMRAD exercise when comparing VMO/VL ratio. Despite current conflicting research this study suggests that by combining the productive movements noted in previous studies, the VMO can be selectively recruited.

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الملخص العربي

رسم العضلات الكهربائي لعضلة الفخذ الداخلية والخارجية أثناء أداء تمارين مفتوحة ومغلقة للساقين

تمثل تزامن أعراض ألام مفصل الردفي الفخذي المسبب الأول لآلام الركبة في الولايات المتحدة الأمريكية . عدم التوازن بين العضلات الخارجية والداخلية لعضلة الفخذ تسبب مشاكل لصابونة الركبة طبقاً للدراسات فإن تقوية العضلة الداخلية الأمامية يقلل من هذه الآلام .

هذه الدراسة تهدف إلى مقارنة نوعين من تمارين تقوية عضلات الركبة (سلسلة التمارين المفتوحة ، سلسلة التمارين المغلقة) وقورنت العضلات برسم نشاط العضلات الكهربائي ، وجدت فروق ذات دلالة إحصائية في نسبة نشاط العضلة الأمامية الداخلية إلى العضلة الأمامية الخارجية .

الخلاصة : التمرين المركب من تمرينات تقوية العضلة الأمامية الداخلية عن طريق فرد الركبة ودورانها للداخل وإبعاد الفخذ يؤدي إلى أعلى معدل لنشاط العضلة الداخلية .

الكلمات الدالة : تمرينات الركبة ، سلسلة تمرينات مفتوحة ومغلقة ، رسم العضلات الكهربائي .