https://doi.org/10.46344/JBINO.2022.v11i02.10

A QUAZI EXPERIMENTAL STUDY TO COMPARE THE EFFECTS OF DIFFERENT EXERCISES ON VMO RECRUITMENT IN NORMAL INDIVIDUALS.

Prof. [Dr.] Mohammed Aslam

Master in Physiotherapy in Neurology, M.I.A.P,H.O.D Physiotherapy/ ProfessorUttaranchal [PG] College of Bio-Medical Sciences and HospitalSewla Khurd, Near Transport Nagar, Saharanpur road, Dehradun [U.K]

ABSTRACT

A total number of 30 subjects of mean age 20.86 ± 1.0635 years were included in the study. The subjects were getting selected randomly. Subjects were asked to perform warm-up exercises i.e. 5 stretches of quadriceps, hamstrings and hip adductors and 2 min walk. Informed consent was taken from them before data collection. All the subjects were instructed and demonstration was given about each testing technique. 30 subjects (N=30) were included with the mean age of 18-30 years. They were randomly performing 3 repetitions of 5 exercises A, B, C, D, E with 3 secs of MVIC and 2 min of rest between each effort. The area under the curve corresponding to the central 1.5 secs of the 3 secs of MVIC was recorded. Surface electrodes were placed for VMO to record recruitment pattern. Analysis for recruitment pattern of VMO between exercises A, B1, B2, C, D & E was done using One-way ANOVA for mean difference of MVIC% of amplitude of recruitment pattern and results did not show any significant difference in recruitment pattern of VMO between the five exercises (p>0.05).

Keywords : MVIC, VMO, MVIC%

Introduction

The vastus medialis obliquus muscle (VMO) performs an important role in the medial patellar stability .*The* vastus mediallis *is* divided into two parts, one proximal called vastus mediallis longus *(VML) and another distal one, the* vastus mediallis obliquus *(VMO)*. These parts show anatomical, functional differences and in the pattern of innervations as well *[1]*. Vastus medialis obliquus is a part of vastus medialis muscle which is one of the four quadriceps muscles of the thigh. The fibers of VMO have more oblique alignment (50°-60°) than other fibers of vastus medialis. It arises from the tendon of adductor magnus, adductor longus & medial intermuscular septum and converges to join other fibers of quadriceps and attaches directly into the medial border of the patella[2]. VMO is able to pull the patella medially [3]. In knee extensor mechanism, the four components of quadriceps (vastus medialis (VM), vastus lateralis (VL), vastus intermedius, and rectus femoris) act together to produce movements. Each component generates tension with a particular magnitude and direction. The resultant knee extension force vector tends to displace patella laterally, attributing to the pull of VL. The rectus femoris and the vastus intermedius are centrally located and their pulls on the patella are exerted along the long axis of the femur. Because the femur deviates laterally from the tibia, they pull proximally and laterally on the patella. In addition, the pull of the vastus lateralis on the patella actually is directed slightly laterally with respect to the femur. However the patellar ligament pulls on the patella in a distal direction. Addition of these forces on the patella yields a force that is directed laterally on the patella[2]. This lateral displacement is resisted by passive constraints eg. congruency of lateral aspect of patella, lateral femoral condyle, medial retinaculum, etc, whereas, vastus medialis obliquus (VMO) has no contribution to knee extension torque but is the only dynamic medial stabilizer which is believed to be important in resisting lateral patellar displacement. Therefore imbalance in the activity of VMO relative to VL was proposed for abnormal patellar tracking. Weakness of VMO allows the patella to track too laterally and may adversely affect the patellofemoral mechanism [4]. Among large variety of pathological conditions affecting knee joint, the patellofemoral pain syndrome (PFPS) is most common [5]. McConnell reports that patellofemoral pain affects one in four of general population [6]. It most commonly affects adolescents and young adults aged between 15 and 35 years, especially female athletes [5]. Patellofemoral pain syndrome is generally considered to result from a combination of several factors, including quadriceps dysplasia, excessive foot pronation, increased Q angle, patella alta, or lateral retinacular tightness. Additionally, researchers and clinicians hypothesize that etiological factors include an imbalance between the vastus medialis oblique and vastus lateralis, but research in this area is conflicting. The vastus medialis oblique (VMO) has an important role as a medial stabilizer of the patella and assists in the normal functioning of the patellofemoral joint. If the VMO atrophies, it is believed that greater lateral deviation of the patella will occur, thus contributing to abnormal patellofemoral joint stress and, ultimately, PFPS. Following this line of reason, rehabilitation specialists and researchers have advocated selective strengthening of the VMO to help restore normal patellofemoral biomechanics and reduce pain [10]. One etiology for anterior knee pain is quadriceps atrophy and/or weakness, particularly the vastus medialis (VM), which leads to an imbalance and maltracking of the patella, resulting in knee pain and/or instability. The line of pull of the quadriceps is relatively valgus with respect to the joint line of the knee. This tends to favor lateral deviation, even if the anatomy is completely normal. The VM is phylogenetically the weakest of the quadriceps group and appears to be the first muscle to atrophy and the last to rehabilitate. According to Carol A Oatis the vastus medialis is approximately 29% of the overall physiological cross sectional area of the vastus medialis complex. The properties of a whole muscle depend not only on the properties of the fibers, but also on the organization of the fibers which rarely run the whole length of the muscle, tending to be somewhat oblique to the muscle's line of action. Peak force production is related to the physiological cross sectional area, which estimates the sum of the cross sectional area of all the fibers. Thus the VMO is more prone to weakness because of its orientation of fibers and its less cross sectional area. EMG studies of non-painful knees show that the ratio of VMO to VL activity is 1:1 and the VMO activity is tonic in nature, in knees with patellofemoral pain the VMO:VL ratio is less than 1:1, it means that VMO fires before in the same time with VL is normal, VL fires before VMO with PFPS. It confirms that motor control dysfunction is a factor in this condition. This change in VMO activity may be the result of the asymmetric wasting of the quadriceps muscle. Some study reported that it takes 20-30 ml of fluid to inhibit the VMO, whereas 50-60 ml of fluid is necessary to inhibit the VL activity. This asymmetry may result in lateral tracking of the patella, which is a common cause of patellofemoral pain [7]. VMO inhibition leads to VMO atrophy which in turn leads to altered mechanics of patellofemoral joint. Quadriceps strengthening exercises, emphasizing the VM, have been suggested as the primary initial management of patellofemoral disorders. In cadaver studies, Ahmed et al. in 1983 showed that the removal of the vastus medialis obliquus (VMO) tension shifted the pressure zone from the center to the lateral facet of the patella. Similarly, Goh et al. in 1995 reported that the absence of VMO caused the patella to displace laterally and increased the load on the lateral patellar facet throughout the range of knee motion. It is generally accepted that the VMO is important for patellar stabilization, in particular through the last 15 degrees or so of extension. As a result, many studies have attempted to determine if any particular exercise was significantly better at isolating the VMO. It has been almost unanimously agreed based on numerous EMG studies that most exercises do not show a clinically significant increase in VMO activity over VLO activity. The electromyography activity of the VMO and VL among individuals with PFPS has been thoroughly investigated through open kinetic chain (OKC) and closed kinetic chain (CKC) exercises. Weight-bearing exercises are more functional than non–weight-bearing exercises because they require multijoint movement, facilitating a functional pattern of muscle recruitment, and stimulate proprioceptors. Because of these advantages, clinicians often recommend weight-bearing exercises in the rehabilitation of PFPS patients [8]. Because fibers of the VMO attach to the adductor magnus muscle, it has been hypothesized that activation of the VMO may be enhanced by combining active knee extension with volitional hip adduction. Open kinetic chain knee extension exercises performed concurrently with hip adduction have not been shown to selectively increase VMO activity. Conversely, squatting exercises that incorporate simultaneous hip adduction and knee extension have been associated with increased VMO activity. Isometric adduction may be useful in facilitating VMO activity during weight bearing as well as in sitting with knee flexed, but has no effect on the quadriceps contraction in non-weight bearing and supine lying. It has been speculated that VMO activity may also be enhanced by combining knee extension exercises with hip abduction. The gluteus medius (GMed) is a prime mover of hip abduction and is also critical to controlling internal rotation of the femur during closed kinetic chain activities. Inability of the GMed to eccentrically control femoral internal rotation and VMO inhibition may both lead to excessive lateral tracking of the patella within the trochlea of the femur. Co-contraction of the GMed and VMO may be advantageous in subjects with PFPS. Lam and Ng reported increased VMO activity with closed chain knee extension exercises performed in a position of medial rotation of the hip compared to neutral or laterally rotated positions [9]. Attempts to develop strengthening exercises that recruit the VMO selectively are, at best, confusing. One study denies any difference in recruitment with knee position and velocity of contraction. another suggests there may be a slight increase in the ratio of VMO to vastus lateralis electrical activity during concentric contractions while stair climbing. Conflicting data exist regarding whether hip position alters the relative activation of the VMO and vastus lateralis during knee extension, but most studies show little effect. A case report suggests that electrical stimulation of the VMO can help prevent lateral dislocation of the patella during its application. However benefits are not apparent after the completion of the stimulation treatment. At the present time the best scientific data available suggest that generalized strengthening of the whole quadriceps femoris muscle is the most successful exercise regimen for anterior knee pain[2]. So rationale behind VMO strengthening exercises is to isolate the VMO and facilitate its contraction and its strengthening thus contributing to normal patellofemoral joint mechanism. There are various controversies behind isolation of VMO for strengthening paved the way for this experimental study. Thus, this study is aimed to expand the work done by various researchers before to identify which exercise is more oriented towards isolated

VMO strengthening and an effort to ensure best professional practice based on research evidence from scientific literature.

Methodology

POPULATION

Target Population: All people who are having week VMO eg. PFPS, O.A. knee etc.

Accessible Population: 500 Normal individual of Dehradun (U.K.) India and 100 girls of Uttaranchal [PG] college of biomedical sciences and Hospital Dehradun (U.K.) India.

RESEARCH SETTINGS

This study was performed in Uttaranchal [P,G] college of biomedical sciences and Hospital Dehradun (U.K.) India

30 female subjects of mean age 20.86±1.0635 years participated in this study.

SAMPLING METHOD

30 subjects got selected on the basis of random sampling.

RESEARCH DESIGN

Present study is quazi experimental in nature.

GROUP ALLOCATION

25 female subjects of UTTRANCHAL COLLEGE OF TECHNOLOGY AND BIOMEDICAL SCIENCES Dehradun & 5 female subjects of Himalaya Institute Hospital were randomly selected.

INCLUSION CRITERIA

1) Young females (18-30 years).
2) Non athlete
3) Individuals having knee ROM of 0°-120°/135°
4) Strength of quadriceps equal bilaterally.
5) No history of trauma or surgery around the knee.

EXCLUSION CRITERIA

1) Persons having any neuromuscular disease.
2) Persons receiving muscle relaxants.
3) Individuals who are having any present or previous record of hip, knee or ankle pathology.

VARIABLES

Dependent variable- Amplitude of recruitment pattern of EMG.

Independent variable- Different exercises to recruit VMO.

INSTRUMENTATION

EMG MACHINE

An electromyographic machine that evaluates the status and function of motor units, muscle fibers and peripheral nerves. Neuroperfect EMG/NCV/EP system: EMG 2000, Medicaid system ISO (9001:2000) was used.

SURFACE ELECTRODES

Small metal disks applied to the skin overlying the appropriate muscle and to monitor EMG signals from large superficial muscles.

GROUND ELECTRODE

An electrode connected to a common source, used to reduce the effect of electrical noise in a recording system. It is attached to the skin near the recording electrodes, but usually not over that muscle.

GONIOMETER

It's a device used to measure the degree of motion given by a joint.

INCH TAPE

To measure the distances from superior pole of patella for VMO electrode placement.

LARGE SCALE

Used to draw a line from medial pole of

patella to the ASIS.

SMALL SIZE FOOTBALL

Small football is placed between thighs for isometric hip adduction.

RELIABILITY OF EMG

EMG is a reliable method for assessing the reproducibility of both the quadriceps and hamstrings muscle activation during either isometric or ballistic exercises. ICC values are greater than 0.90[17].

PROCEDURE RELIABILITY

Intrasession ICCs for the percentage of MVIC between trials ranges from 0.67 to 0.99. Intersession reliability ranges from 0.06 to 0.83[16].

PROTOCOL

30 subjects (N=30) of age 18-30 were get selected randomly

⇓

Informed consent and ethical approval was taken

⇓

Warm-up

⇓

Electrode placement at VMO

⇓

Recruitment pattern(RP) was recorded during reference activity

⇓

Subjects were randomly performing all 5 exercises

⇓

Record RP (A) of VMO for each exercise

Exercise A : Open kinetic isometric hip adduction against ball between thighs along with isometric Knee extension.

Exercise B : VMO ball squat : hip adduction against ball between thighs along with mini squat (B2) as well as ascending from squat (B1).

Exercise C : Open kinetic isometric hip abduction along with isometric knee extension.

Exercise D : Open kinetic isometric tibial internal rotation along with isometric knee extension .

Exercise E : Standing against wall : isometric hip external rotation with the knee in 60° flexion and foot 10° supination and opposite limb off the floor against the wall.

PROCEDURE

The subjects were getting selected randomly. Subjects were asked to perform warm-up exercises i.e. 5 stretches of quadriceps, hamstrings and hip adductors and 2 min walk. Informed consent was taken from them before data collection. All the subjects were instructed and demonstration was given about each testing technique. 30 subjects (N=30) were included with the mean age of 18-30 years. They were randomly performing 3 repetitions of 5 exercises A,B,C,D,E with 3 secs of MVIC and 2 min of rest between each effort . The area under the curve corresponding to the central 1.5 secs of the 3 secs of MVIC was recorded. Surface electrodes were placed for VMO (refer Appendix D) to record recruitment pattern.

REFERENCE ACTIVITY (MVIC) :

Subjects sat comfortably on a couch with the hips 90^0 flexed, no abduction at the hips , knees 60^0 flexed. A mobilization belt was placed around the subject's ankle and attached to a force bar secured to the floor. The set-up was such that when the slack was taken up from the ankle strap, the knee angle was in 60˚ of flexion. The hip and knee angles were measured with a standard goniometer. Subjects were asked to extend the knee against the resistance of the belt as maximally as she can (MVIC). 3 repetitions with 3 secs hold and 10 secs rest between each effort. Electrode placement was same for the whole session.

EXERCISE A

Subjects sat comfortably on a couch with the hips 90^0 flexed , knees 60^0 flexed and a small ball was there between thighs. A mobilization belt was placed around the subject's ankle and attached to a force bar secured to the floor. The set-up was such that when the slack was taken up from the ankle strap, the knee angle was in 60˚ of flexion. The hip and knee angles were measured with a standard goniometer. Subjects were asked to adduct hips against ball along with isometric knee extension as maximally as he/she can (MVIC). 3 repetitions with 3 secs contractions and 10 sec rest between each effort and 2 min interval between each exercise. Electrode placement was same for the whole session.

EXERCISE B

Subjects were asked to stand on the floor with the shoes-off , hips in neutral position, knees in 60˚ flexion(squat position), trunk straight, and ball between thighs. The hip and knee angles were measured with a standard goniometer. Subjects were asked to adduct hips against ball as maximally as she can (MVIC) along with knee extension. Both ascending & descending phases of a squat were recorded. 3 repetitions with 3 secs hold and 10 secs rest between each effort and 2 min interval between each exercise. Electrode placement was same for the whole session.

EXERCISE C

Subjects sat comfortably on a couch with the hips 90^0 flexed, no abduction at the hips , knees 60^0 flexed. A mulligan belt was placed around the subject's ankle and attached to a force bar secured to the floor. The set-up was such that when the slack was taken up from the ankle strap, the knee angle was in 60˚ of flexion. Another mulligan belt was secured around the thighs to provide resistance for hip abduction. The hip and knee angle were measured with a standard goniometer. Subjects were asked to abduct hips isometrically along with isometric knee extension as maximally as she can (MVIC). 3 repetitions with 3 secs contractions and 10 secs rest between each effort and 2 min interval between each exercise. Electrode placement was same for the whole session.

EXERCISE D

Subjects sat comfortably on a couch with the hips 90^0 flexed, no abduction at the hips , knees 60^0 flexed and leg in 30^0 external rotation. A mulligan belt was placed around the subject's ankle and attached to a force bar secured to the floor. The set-up was such that when the slack was taken up from the ankle strap, the knee angle was in 60˚ of flexion. Another mulligan belt was used to provide resistance to internal rotation of leg. The hip, knee and foot angles were measured with a standard goniometer. Subjects were asked to do isometric internal rotation of leg along with isometric knee extension as maximally as she can (MVIC). 3 repetitions with 3 secs of contractions and 10 secs rest between each effort and 2 min rest between each exercise. Electrode placement was same for the whole session.

EXERCISE E

Subjects were asked to stand on the floor with the shoes-off with the non-tested leg against the wall and off the floor. Tested leg's Hip in slight external rotation, knee in 60° flexion and foot in 10° supination. Subjects will be asked to perform isometric hip external rotation (MVIC). 3 repetitions with 3 secs contractions and 10 secs rest between each effort and 2 min interval between each exercise. Electrode placement was same for the whole session.

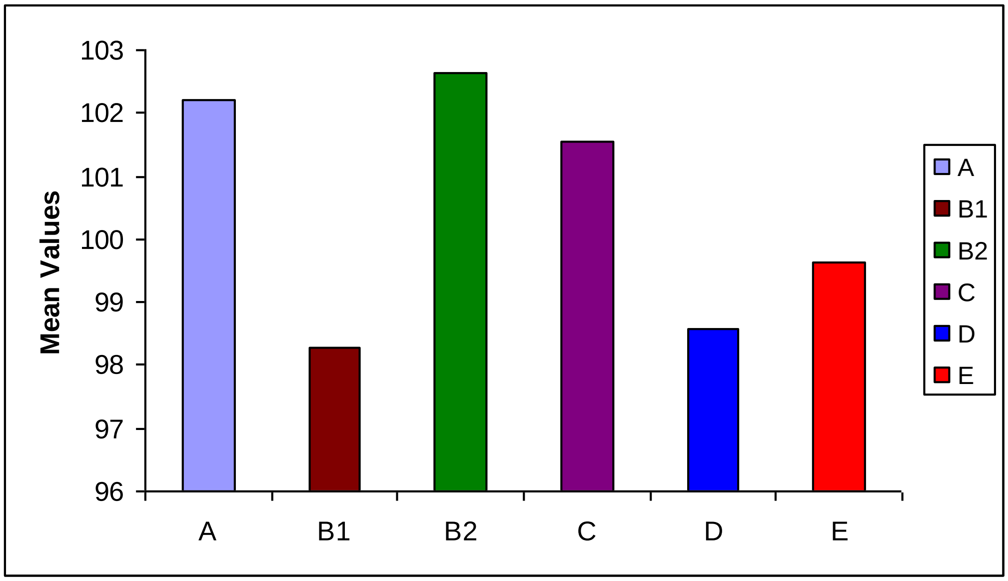
Instruments

Exercise – A **Exercise - B**

Exercise- C

Comparison of mean value of MVIC % of recruitment pattern between exercises A, B1, B2, C, D & E

Comparison of mean value of MVIC% of recruitment pattern between exercises A, B1, B2, C, D and E



DISCUSSION

The comparison of mean difference of MVIC% of recruitment pattern between exercises A,B1,B2,C,D & E showed no significant difference between exercises but marginally better amplitude with dynamic eccentric exercise i.e. descending phase of VMO ball squat(102.63), followed by exercise A i.e. isometric knee extension along with isometric hip adduction(102.20) & exercise C i.e. isometric knee extension along with isometric hip abduction(101.54) and minimum amplitude was seen in exercise B1 i.e. ascending phase of VMO ball squat(98.29).

VMO BALL SQUAT & OPEN KINETIC ISOMETRIC KNEE EXTENSION ALONG WITH ISOMETRIC HIP ADDUCTION: The findings of our study are in accordance with findings of the Brownstein et al who suggested that simultaneous activation of knee extensors and hip adductors might provide the VMO with a more stable origin and thus facilitate preferential activity of this component of the quadriceps[9]. As the fibers of the VMO attach to the adductor magnus muscle, it has been hypothesized that activation of the VMO may be enhanced by combining active knee extension with volitional hip adduction. Open kinetic chain knee extension exercises performed concurrently with hip adduction have not been shown to selectively increase VMO activity. Conversely, squatting exercises that incorporate simultaneous hip adduction and knee extension have been associated with increased VMO activity[8]. During squatting quadriceps contracts eccentrically and it has been hypothesized that eccentric contractions produce more force than either isometric or concentric contractions. Maximum eccentric strength is estimated to be between 1.5 and 2.0 times maximum concentric strength[14]. Tang et al also observed significant differences in the VMO:VL relation during concentric and eccentric phases of squat exercise between 0-90^{o} knee flexion; however they observed a better VMO:VL relation during phases evaluated of the squat exercise at 60^{0} knee flexion[11]. Vastus medialis obliquus (VMO) has no contribution to knee extension torque but is the only dynamic medial stabilizer[4] , may be the reason why dynamic exercises better recruit VMO. Hodges and Richardson found a greater increase in VMO activity compared with VL activity when hip adduction was added to an isometric knee extension exercise in both weight-bearing and nonweight-bearing conditions [9]. Weight-bearing exercises are more functional than non-weight-bearing exercises because they require multijoint movement, facilitating a functional pattern of muscle recruitment, and stimulate proprioceptors[8]. Data found by Cerny concluded that the wall slide squat exercise performed at 60˚ presented higher activity of patella stabilizer muscles as compared to wall slide squat exercise performed at 45˚. Anderson et al who verified increase on the EMG activity of VMO and VL muscles with the increase on knee flexion during squat exercise. According to these authors, this occurs due to the increase on knee flexion in CKC, the rectus femoris is more active and hence the VMO should also increase its EMG activity in order to maintain the patella in its adequate alignment[10].

OPEN KINETIC ISOMETRIC KNEE EXTENSION ALONG WITH ISOMETRIC HIP ABDUCTION: The gluteus medius (GMed) is a prime mover of hip abduction and is also critical to controlling internal rotation of the femur during closed kinetic chain activities. Inability of the GMed to eccentrically control femoral internal rotation and VMO inhibition may both lead to excessive lateral tracking of the patella within the trochlea of the femur [8].GMed strengthening is important to consider so that it does not let the femur go for excessive internal rotation during close kinetic chain activities and prevent ELPS (Excessive Lateral Pressure Syndrome) of the knee.

OPEN KINETIC ISOMETRIC TIBIAL INTERNAL ROTATION ALONG WITH ISOMETRIC KNEE EXTENSION: It has been suggested that the VMO might have some internal rotation effect on the tibia, based on the observation that the lowermost fibers of the VMO attach to the anteromedial aspect of the tibia[15]. But our findings did not support the findings of the Brownstein et al that the VMO can be preferentially recruited through active medial rotation of the tibia[9]. Hanten and Schulthies reported no preferential recruitment of the VMO with resisted medial tibial rotation in healthy subjects. The maneuver, however, was not combined with active or resisted knee extension[9].

ISOMETRIC HIP EXTERNAL ROTATION AGAINST THE WALL WITH THE KNEE IN 60˚ FLEXION AND FOOT 10˚ SUPINATION: External rotator strengthening prevents excessive internal rotation of the femur during close chain activities and with knee 60˚ flexion quadriceps contracts eccentrically. Gabriel Ribeiro et-al suggest that different foot positions during one-legged squat do not cause changes in muscle recruitment[12]. During single-legged squat, the electromyographic behavior of the quadriceps musculature was studied associated to different foot stances in the medium-lateral direction. In this study, no differences were observed in the electromyographic behavior (EMG) of two uniarticular units: vastus medialis oblique and vastus lateralis muscles. On the other hand, Hertel et al. found differences in the EMG activity pattern in this very task using an orthosis for correction of foot pronation and supination[11]. Christina D. Davlin et-al suggest that different hip positions: the anatomically neutral hip position, external hip rotation and internal hip rotation has no effect on the VMO:VL ratio[18].

LIMITATIONS OF THE STUDY

1) PFPS patients or patients with inhibited VMO were not included in the study.
2) Only one dynamic exercise was included.

FUTURE RESEARCH

1) This can be done on patients having PFPS or inhibited VMO.
2) Few more exercises can be included for comparison.
3) These exercises can be compared at different knee, foot and hip angles.
4) EMG study of other muscles of the lower extremity can be done with these exercises.

CONCLUSION

The result of this study shows that VMO recruitment is marginally better with dynamic eccentric exercise involving isometric hip adduction i.e. VMO ball squat although there is no significant difference between exercises.

SOURCE OF FUNDING – From Uttaranchal [PG] College of Bio-medical Sciences and Hospital.

ETHICAL CLEARENCE – It is abonafide work done by me and I have not taken any part of thesis from anywhere.

REFERENCES

1) Carol A. Oatis: Kinesiology; the Mechanics and Pathomechanics of Human Movement, 742-744.
2) Toumi H et al : New insights into the function of the vastus medialis with clinical implications, Med Sci Sports Exerc 39 (7): 1153-9, 2007.
3) Am Fam Physician: Patellofemoral Pain Syndrome: A Review and Guidelines for Treatment 1999;60:2012-22.
4) Santos EP: Electromyographic activity of vastus medialis obliquus and vastus lateralis muscles during functional activities in subjects with patellofemoral pain syndrome, Rev Bras Fisioter, 2008;12(4),304-10.
5) Christopher M.: Rehabilitation of Patellofemoral Joint Disorders: A Critical Review, JOSPT, Volume 28, Number 5, November 1998.
6) Liu Chunlong : Elecromyographic Biofeedback as Treatment or Training the Vastus Medialis Obliquus Vastus Lateralis in Patients with Patellofemoral Pain Syndrome 2005.
7) Michelle C. Boling et al : Outcomes of a weight-bearing rehabilitation program for patients diagnosed with patellofemoral pain syndrome : Vol 87, issue 11, 1428-1435/ 2006.
8) J Hertel et al : Combining isometric knee extension exercises with hip adduction does not increase quadriceps EMG activity, Br J Sports Med 2004;38:210-213.
9) Judi Laprade et al: Comparison of five isometric exercises in the recruitment of the vastus medialis obliquus in persons with and without patellofemoral pain syndrome, JOSPT, Volume 29, Number 3, March 1998: 197-204.
10) Debora Bevilaqua-Grossi et al : Electromyographic activity evaluation of the patella muscles during squat isometric

exercise in individuals with patellofemoral pain syndrome, Vol.11, no.3/2005, 1-11.

11) Gabriel Ribeiro et al : Electromyographic activity during one-legged squatting under different foot positions : Vol 13, No.1/2007, 36-39.

12) Jun Kimura (2001), Ch-13, Techniques to assess muscle function, 3rd edition; 322.

13) Carol A. Oatis: Kinesiology; the Mechanics and Pathomechanics of Human Movement: part 1, ch. 4;58.

14) Thomas Souza et-al, Knee Rehabilitation Part II, chiroweb.com, Vol.17, Issue 04 (Feb 2008)

Teddy W Worrell: Electromyographic reliability and analysis of selected lower extremity muscles during lateral step-up conditions, Journal of Athletic Training 1998;33(2):156-162.

15) Fauth, McKenzie L et al: Reliability of Surface Electromyography During Maximal Voluntary Isometric Contractions, Jump Landings, and Cutting, Journal of Strength and Conditioning Research: April 2010 - Volume 24 - Issue 4 - pp 1131-1137.

16) Christina D. Davlin et-al : The effect of hip position and electromyographic biofeedback training on the Vastus medialis oblique:Vastus lateralis ratio, Journal of Athletic Training, Vol.34, No.4 (December 1999).

17) Cowan SM, Bennell KL et-al, Archives of physical medicine and rehabilitation, Volume 82, Issue 2, Pages 183-189 (February 2001).