

# EFFECT OF FUNCTIONAL STABILIZATION TRAINING ON PAIN AND MUSCLE ACTIVATION RATIO OF VASTUS MEDIALIS OBLIQUUS AND VASTUS LATERALIS IN INDIVIDUALS WITH PATELLOFEMORAL PAIN: A RANDOMIZED CONTROL TRIAL

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## ABSTRACT

**Background:** Patients with patellofemoral pain(PFP) demonstrate impaired lower-limb and trunk movement control along with hip and trunk muscle weakness. Functional stabilization training (FST) is a treatment focused on hip muscle strengthening and lower-limb and trunk movement control. The objective of the study is to examine the effectiveness of functional stabilization training on pain and electromyographic muscle activation ratio for VMO and VL in individuals with PFP.

**Methodology:** Study has been conducted on 60 patients diagnosed with PFP. Written informed consent was obtained from the patients. All the patients were randomly allocated into two groups for 8 weeks of intervention. Outcome measurements were numeric pain rating scale (NPRS) and electromyographic muscle activation ratio for VMO and VL.

**Results:** The results showed that there is statistically high significant difference( $p < 0.05$ ) showing improvement in means of NPRS and electromyographic muscle activation ratio for VMO and VL before and after intervention in both the groups but FST group shows more significant improvement in NPRS( $p = 0.000$ ) and in VMO:VL( $p = 0.000$ ) compared to CT group.

**Conclusion:** FST group showed more benefits than CT group in individuals with PFP in relieving pain and improving balance in the activity of VMO and VL.

**KEY WORDS:** Core stability, Electromyography, Hip muscles, Functional stabilization training, Patellofemoral pain, Vastus medialis obliquus, Vastus lateralis.

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## INTRODUCTION

Patellofemoral pain syndrome (PFPS) is one of the most common syndrome among physically active individuals between the ages of 15 and 30 [1]. It can be defined as retro-patellar or

peri-patellar pain aggravated by activities stressing the patellofemoral joint, such as squatting, prolonged sitting, stair climbing and running [2,3]. It is a condition seen in orthopedic and sports medicine practice with an incidence rate

among the general population being as high as 40% [4]. Prevalence of patellofemoral pain is estimated to be between eight to 40%. Most causes of anterior knee pain in adolescent Indian population involve the patellofemoral joint and the extensor mechanism of the knee [5]. The vastus medialis oblique (VMO) is active stabilizer of the patella. This part of the VMO muscle originates from the medial aspect of the distal femur and crosses horizontally to insert into the medial aspect of the patella through the medial retinaculum. The orientation of these fibers affects lateral shifting of the patella during active knee extension [6]. Lateral pull of large VL muscle is counterbalanced by VMO under normal circumstances to ensure patellar stability. The VMO and VL muscles co-contract with each other and maintain the location of the patella in the patellofemoral joint during movements [3].

VMO weakness causes lateral shifting and tracking of the patella which happens in the last 30° of extension. It will lead to reduction in contact area of patellofemoral joint and increased patellofemoral stress [7]. Ott et al. found that there was reduced VMO and VL activation with increase in anterior knee pain in patients who had PFPS [8]. PFPS does not occur because ideal VMO:VL ratio is 1 which shows that patella does not slide off the femoral groove [9]. In conventional closed kinetic chain exercises, VMO:VL ratio nearly approximates to 1. With regard to VMO:VL activation patterns, Individuals with PFP may differ from healthy individuals [10]. 1:1 ratio or the approximation of a 1:1 ratio for the VMO and VL is the expected target ratio for PFPS patients to become pain free [6]. maintaining patellar alignment in the trochlear groove of the femur is necessary to restore functional efficacy of the patellofemoral joint [4]. Physical therapy has constantly been found to be effective in reducing pain in patients with PFPS, with treatment programs traditionally focusing on increasing quadriceps strength and VMO function [2]. Functional stabilization training is a treatment for individuals with patellofemoral pain which is focused on hip muscle strengthening and lower-limb and trunk movement control which affects trunk muscle endurance and trunk kinematics, knee function, lower-limb and eccentric

hip and knee strength [11]. Many studies have investigated the effect of the proximal musculature, including the hip girdle and lumbo-pelvic region on knee [12-14]. Primary function of the gluteal muscles is to extend, abduct and externally rotate the hip. In addition to this, they assist in extension of the knee by virtue of their insertion into the iliotibial tract. Weakness of these muscles can also influence patellar tracking [7].

Movement at knee can be influenced by frontal plane motions of the pelvis and trunk [15]. Ipsilateral trunk lean during functional activities may cause the ground reaction force vector to pass lateral to the center of the knee joint, which creates a valgus movement at the knee. A higher valgus movement at knee can increase the dynamic quadriceps angle which consequently increases lateral vector force acting on the patella. This may result in increased stress on the lateral compartment of the patellofemoral joint [16]. Lumbo pelvic musculature (commonly known as core) is required to control movements of the distal segments during weight-bearing functional activities and stabilization of pelvis [17]. Recent study has reported that a treatment program which focuses on hip strengthening associated with core training and functional exercises can improve the motor learning of the proper dynamic lower limb alignment [18].

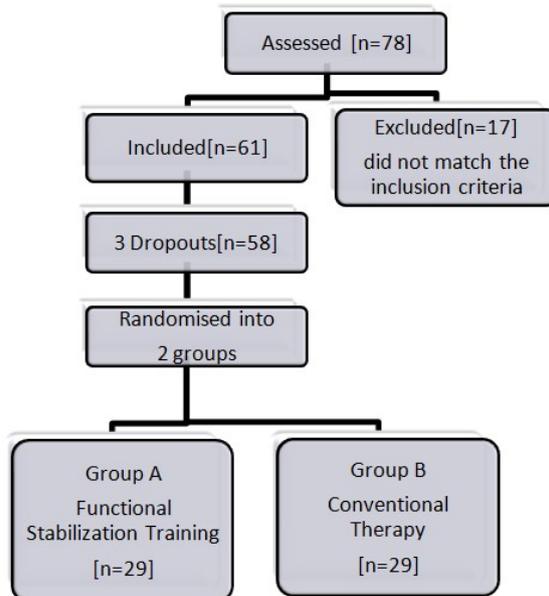
Although it has been suggested that weakness of trunk and hip musculature might be involved in PFPS development, few studies have investigated the biomechanical effects of a training program focusing on trunk and hip weaknesses in individuals with PFPS [19]. Weakness of VMO in relation to VL and abnormal counteraction of VMO and VL muscles in individuals with PFPS are very crucial components to be taken into consideration while dealing with PFPS.

## **MATERIALS AND METHODOLOGY**

A randomized, comparative-controlled, single-blinded study was performed at Parul University. 60 Patients either male or female aged between 18 to 30 years having pain in anterior knee or retropatellar area during at least 2 or more of the following activities: ascending and/or descending stairs, prolonged sitting, run

ning, jumping, squatting, kneeling for more than 3 months were recruited from Parul Sevashram Hospital, Physiotherapy OPD. Patients were excluded if they had any intra-articular pathology; Osgood-Schlatter or Sinding Larsen-Johansson syndrome; involvement of cruciate or collateral ligaments; patellar instability; hip pain; previous surgery in the lower limb; knee joint effusion; or if palpation of the iliotibial band, patellar tendon, or pes anserinus tendons produces the pain. Eligible patients were divided into two groups by computer generated method **Group-A** (Functional Stabilization Training Group - FST Group) and **Group-B** (Control Group - CT Group). A baseline assessment was carried out for each patient, followed by an 8 weeks intervention, 3 sessions per week (Appendix A). Patients were assessed at baseline and at the end of the intervention. All patients read and signed an informed consent form approved by the Parul University Institutional Ethics Committee for Human Research (PU-IECHR).

Fig. 1: Sample Size and Randomization.



Numeric Pain Rating Scale was used to assess presently perceived pain in activity of daily life before starting the study. The subjects were asked to rate their pain between 0 to 10 [30]. Surface Electromyography (EMG) was done for muscle activation ratio of Vastus Medialis Obliquus and Vastus Lateralis [9,20]. For surface Electromyography, prior to the placement of electrodes, the skin was prepared by cleaning the appropriate areas with alcohol wipes. Surface EMG with 20mm inter electrode separation

was used. For the VL, an electrode was placed on the line between the outer side of the patella and the anterior superior iliac spine and was located 10cm from the patella. For the electrode placement of VMO muscle, an electrode was placed on the line forming an angle of 50° with the parallel line between the lateral aspect of the patella and the anterior superior iliac spine which was located 4cm from the patella. (Fig. 2) Surface EMG recordings during exercises had excellent test-retest reliability and high interclass correlation coefficients of 0.89 for the VMO and 0.95 for the VL. Then the subjects were requested to perform single leg squat on affected leg. Best of the three recordings was taken for both VMO and VL muscles. The ratio of VMO and VL was calculated for each subject [9].

**Statistical analysis:** Statistical Package for Social Sciences (SPSS) v20 was used for the data analysis. Paired t test and Wilcoxon signed rank test were used to find the significance of parameters pre and posttest. Unpaired t test and Mann-Whitney test were used to find the significance of difference between two groups.

## RESULT

Average age of both groups and gender distribution in the study are shown in table 1 and fig 2 respectively. A summary of changed scores and mean differences for each of the outcome measure are presented in table 2. Negative change in scores on NPRS and higher change which is near to 1 for VMO:VL are indicative of improvement; A main effect for change over time was demonstrated as both groups significantly improved in all outcome measures by the end of 8 weeks. There is statistically high significant difference ( $p < 0.05$ ) which suggests improvement in means of NPRS and VMO:VL for treatment before and after intervention in both the groups but group A showed more significant improvement compared to group B. The group B showed comparatively lower changes in any of the outcome measures. The mean of NPRS for Group A was 1.41 with the SD of 0.05. When it was compared with the mean of NPRS for Group B which was 3.03 after 8 weeks of intervention with the SD of 1.01, the obtained z-value was 5.70. This finding had

showed that there is a highly significant difference in NPRS for Group A and Group B ( $p < 0.005$ ). Mean difference of Group A showed high significant improvement compared to mean difference of Group B after 8 weeks of intervention. The mean of VMO:VL for Group A was 1.01 with the SD of 0.08. When it was compared with the mean of VMO:VL for Group B which was 0.70 after 8 weeks of intervention with the SD of 0.14, the obtained z-value was 10.08. This finding had showed that there is a highly significant difference in VMO:VL for Group A and Group B. ( $p < 0.005$ ) Mean difference of Group A showed high significant improvement compared to mean difference of Group B after 8 weeks of intervention.

**Table 1:** Average Age of Both Groups.

Group	No. of Patients	Mean Age	±SD
Group A	29	20.55	1.88
Group B	29	20.41	1.93
Total	58		

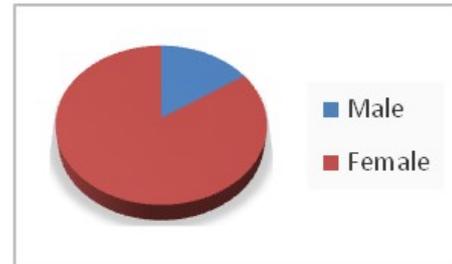
**Table 2:** Intra Group comparison of the treatment on Pain and Muscle Activation Ratio of VMO and VL.

	Mean	SD	df	z-value	p-value
<b>NPRS in Group A</b>					
pre	4.59	1.08	28	4.75	0
post	1.41	0.5			
<b>NPRS in Group B</b>					
pre	4.17	1.16	28	4.44	0
post	3.03	1.01			
<b>VMO:VL in Group A</b>					
pre	0.65	0.16	28	11.09	0
post	1.01	0.08			
<b>VMO:VL in Group B</b>					
pre	0.66	0.15	28	4.86	0
post	0.7	0.14			

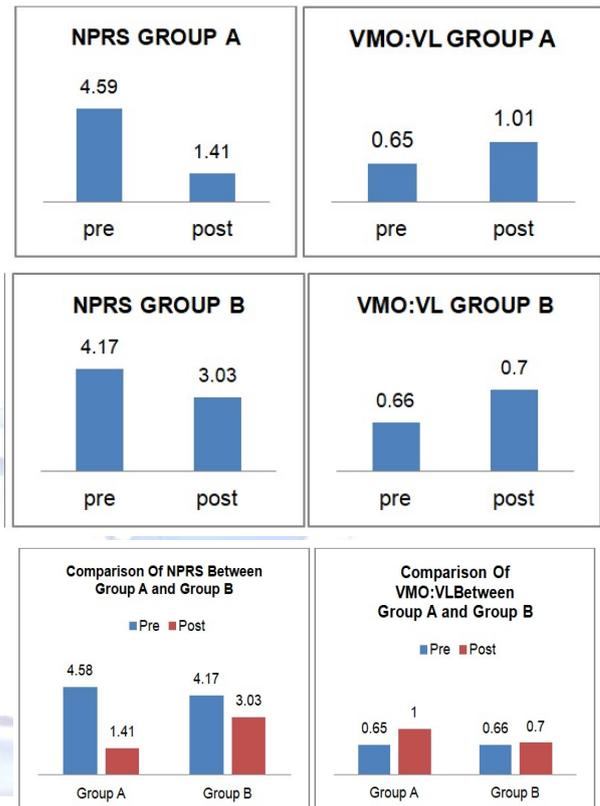
**Table 3:** Inter Group comparison of treatment on Pain and Muscle Activation Ratio of VMO and VL.

	Group A	Group B	df	Z-value	P-value
<b>Comparison of NPRS between Group A and Group B</b>					
Mean	1.41	3.03	58	5.7	0
SD	0.05	1.01			
<b>Comparison of VMO:VL between Group A and Group B</b>					
Mean	1.01	0.7	58	10.08	0
SD	0.08	0.14			

**Fig. 2:** Gender Distribution.



**Fig.3:** Comparison of treatments on Pain and Muscle Activation Ratio of VMO and VL.



**Fig. 4:** Hip abduction/lateral rotation/extension in side lying.



**Fig. 5:** Hip extension and lateral rotation in prone.



**Fig. 6:** Transverses abdominis and multifidus muscle training with physio ball.



**Fig. 7:** Isometric hip abduction/lateral rotation in standing.



**Fig. 8:** Single leg dead-lift.



**Fig.9:** Hip abduction/lateral rotation with slight knee and hip flexion in side lying.



**Fig. 10:** Ventral bridge.



**Fig. 11:** Lateral bridge.



**Fig. 12:** Trunk extension on physio ball.



## DISCUSSION

This study showed that individuals who participated in a treatment protocol with hip muscle strengthening and lower-limb and trunk movement control exercises experienced improvements in the approximation of a 1:1 ratio for the VMO and VL muscles which has decreased patellofemoral joint stress which has further decreased pain at patellofemoral joint compared to the individuals who participated in a treatment program focusing mainly on quadriceps strengthening. The aim of this study was to study the effect of functional stabilization training which focuses on hip muscle strengthening as well as lower limb and trunk movement control on balancing in the patellar tracking mechanism between VMO and VL in individuals having patellofemoral pain. Trunk stabilization in functional stabilization training provide proximal stability which helps in improving abnormal

lateral tracking mechanism of patella in femoral groove by counterbalancing actions of VMO and VL. Strengthening of posterolateral musculature helps in reduction of VMO weakness which causes lateral shifting and tracking of the patella during the last 30° of extension. This leads to attenuation in patellofemoral contact area and increased patellofemoral stress.

Both groups experienced clinically and statistically significant improvements in pain after the intervention but it should be noted that group A (FST Group) showed more significant improvement in mean differences after the 8 weeks of intervention compared to group B (CT Group).

As stated by Daniel R Souza et al., In traditional closed kinetic chain exercises, VMO:VL ratio mostly approximates to 1. Individuals with PFP may differ from healthy individuals with regard to VMO:VL activation patterns [10]. 1:1 ratio or the approximation of a 1:1 ratio for the vastus medialis oblique and vastus lateralis is the desired target ratio for patellofemoral pain syndrome patients.

Although the higher incidence in females, PFP also occurs in male quite commonly. Theresa H. Nakagawa et al. studied the differences among genders in knee, hip, pelvis and trunk kinematics, hip strength, and gluteal muscle activation during the performance of a single-leg squat in individuals with PFPS and normal participants [16]. They concluded that compared to normal participants, males and females with PFPS showed increased knee abduction, hip adduction, contralateral pelvic drop and ipsilateral trunk lean during a single-leg squat. Along with the altered kinematics, there was reduced strength of the hip external rotators and abductors as measured eccentrically on an isokinetic dynamometer. Additionally, females with PFPS showed decreased gluteus medius activation and increased hip internal rotation during the single-leg squat compared to males.

Lori A Bolga et al. studied the differences between hip and knee strength with EMG activity during stair descending in females with and without PFPS. This study showed that subjects with PFPS had hip lateral rotator and abductor muscle weakness [13].

In a systemic review, Erik P. Meira et al. concluded that there is association between the position and strength of the hip with PFPS. Once symptomatic, such patients had a common deficit. Hip strengthening and a coordination exercise protocol can be useful in a traditional treatment plan for PFPS [21]. Powers C. et al. compared patellar tracking and tilting during non weight bearing and weight bearing activities in females with lateral patellar subluxation using dynamic magnetic resonance imaging techniques [22]. Patella tracks and tilts laterally on a stable femur in non weight bearing. In weight bearing, the femur rotates internally, which causes patella to track laterally in relation to the femur. Two studied the PFPS patients and found that they had double the femoral internal rotation compared to the control group [23,24]. This indicates the association between PFPS and hip strength/coordination.

Catherine L. Mascal et al. presented a case report of two patients who had weakness of the hip extensors, external rotators and hip abductors which was demonstrated by hand-held dynamometry testing. In these cases, a 14-week intervention was given focusing on recruitment and endurance training of the trunk, pelvis and hip muscles. Functional status, muscle force production, pain along with subjective and objective assessment of lower limb kinematics during a step-down maneuver and gait were assessed pre and post intervention. Both patients had a significant improvement in patellofemoral pain, lower limb kinematics during dynamic testing, and were able to return to their functional activities. They concluded that Assessment and treatment of the pelvis, hip and trunk muscles should be considered in the rehabilitation of patients who present with patellofemoral pain and demonstrate abnormal lower limb kinematics [25].

Ann-Katrin Stensdotter et al. conducted a study to assess if the quadriceps femoris muscle is activated in a different manner in closed versus open kinetic chain activities. The result of this study showed that the onset of EMG activity of different muscle portions of the quadriceps was more simultaneous in closed chain knee extension activities than in the open chain activities.

Rectus femoris had the earliest EMG onset while VMO was activated last with smaller amplitude in open chain than in closed chain [26]. These findings support the method of performing electromyography for VMO and VL for obtaining the ratio VMO:VL.

Compared to Open Kinetic Chain exercises, Closed Kinetic Chain exercises provide greater simultaneous activity with earlier onset and higher amplitude of EMG activity in VMO in different parts of the quadriceps muscle. As muscle function is known to have significant influence on the knee joint biomechanics, closed kinetic chain exercises can provide more accurate loading conditions for the patellofemoral joint because of more central tracking of the patella [27]. Christopher M Powers et al. conducted a study to know if there are changes in the activity of the vastus muscles that could be the cause of patellar instability in individuals with PFP. Their results showed that timing or intensity changes between the VMO and VL muscles were not associated with PFP [28]. Whereas, Daniel R Souza et al. conducted a study aiming to compare VMO:VL EMG ratios of healthy individuals and patients with unilateral PFPS. The study concluded that individuals with PFPS are different from healthy individuals in terms of their VMO:VL activation patterns. This factor may interact with biomechanical factors in explaining the cause of PFPS syndrome [10]. The presence of diminished VMO:VL EMG ratios in both knees of the patients with unilateral PFPS suggests that abnormal muscle activation patterns may interact with biomechanical factors in explaining the cause of unilateral PFPS.

## CONCLUSION

During the course of this study, it has been concluded that Functional Stabilization Training and Conventional therapy both have improved pain and electromyographic muscle activation ratio of VMO:VL in individuals with PFPS. There is significant improvement in both the groups after 8 weeks of treatment program but the group receiving Functional Stabilization Training showed more powerful improvement in pain and electromyographic muscle activation ratio of VMO:VL in individuals with PFPS.

**Limitations:** The study consisted of smaller number of subjects. No follow ups were taken. Long term effects were not analysed for the patients participated in the study.

## Future research:

Future studies should be done on bigger sample size in both the groups. The duration of the study should be elongated for the better effectiveness of this exercise intervention. Further study can be done to determine the clinical applicability of these exercise regimes for different age groups, to know the effectiveness of this exercise intervention in various populations depending on their occupations and to determine the effectiveness of this intervention on EMG activities of hip abductor and external rotators.

**Conflicts of interest: None**

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## **Appendix A**

### **Treatment protocol performed by the patients in Group A (FST Group)**

#### **Week 1 to 2:**

1. Transversus abdominis and multifidus muscle training with physio ball (5 repetitions with 20 sec. isometric hold)
2. Isometric hip abduction/lateral rotation in standing (2 sets of 20 repetitions with 5 sec. isometric hold)
3. Hip abduction/lateral rotation/extension in side lying (2 sets of 20 repetitions with 5 sec. isometric hold – 20 % of 1 RM)
4. Hip extension/lateral rotation in prone (2 sets of 20 repetitions with 5 sec. isometric hold – 20% of 1 RM)
5. Hip abduction/lateral rotation with slight knee and hip flexion in side lying (2 sets of 20 repetitions with 5 sec. with theraband)

#### **Week 3 to 5:**

1. Lateral bridge and ventral bridge (5 sets of 30 sec. hold)
2. Trunk extension on physio ball (3 sets of 12 repetitions)
3. Hip abduction/lateral rotation/extension in side lying (3 sets of 12 repetitions – 75% of 1 RM)
4. Hip extension/lateral rotation in prone (3 sets of 12 repetitions – 75% of 1 RM)
5. Hip abduction/lateral rotation with slight knee and hip flexion in side lying (3 sets of 12 repetitions with theraband)
6. Pelvic drop in standing (3 sets of 12 repetitions – ankle weight 75% of 1 RM)
7. Hip lateral rotation in closed kinetic chain (3 sets of 12 repetitions with theraband)
8. Single leg deadlift (3 sets of 12 repetitions with theraband)

#### **Week 6 to 8:**

Exercises [1 to 8] will remain same as prescribed in week 3 to 5

1. Single leg squat with elastic band resistance

### **Treatment protocol for group B (CT group)**

#### **Week 1 and 2:**

1. stretching of the quadriceps, gastrocnemius, iliotibial band and hamstrings (3 sets of 30 repetitions)

-open and closed chain exercises for quadriceps strengthening.

2. Straight leg raise in supine (2 sets of 20 repetitions)
3. Seated knee extension (2 sets of 20 repetitions with 50% of 1 RM)
4. leg press (2 sets of 20 repetitions with 50% of 1 RM)
5. wall squat (2 sets of 20 repetitions with 5 sec. isometric hold)

#### **Progression in week 3 to 5:**

Exercises [1 to 4] will be given with 3 sets of 12 repetitions with 10 sec isometric hold]

1. Addition of Step-ups and Step-downs (3 sets of 12 repetitions)

#### **Progression in week 6 to 8: same as in week 3 to 5.**

1. single leg standing on unstable surface (3 sets of 30 sec hold)