



Effect of Dynamic strengthening for quadriceps muscle (vastus medialis obliquus) on Patellar tracking among young females with Patellofemoral Pain Syndrome

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ABSTRACT

Background:

The patellofemoral joint is diarthrodial plane joint that consist of posterior surface of patella (kneecap) and trochlear surface of distal anterior femur (thigh bone), quadriceps muscles and articular cartilage. Vastus medialis obliquus (VMO) played an important role in controlling the contact area and pressure distribution in Patellofemoral joint. Patellofemoral pain syndrome (PFPS) is the most common cause of knee pain. The term PFPS is often used interchangeably with anterior knee pain.

Vastus medialis obliquus (VMO) activation during exercise, general quadriceps strengthening does benefit many patients with PFPS and is considered the gold standard treatment. The stability of patellofemoral joint involves dynamic and static stabilizers which control movement of patella within the trochlea, referred to as patellar tracking.

Aim:

The aim of this research is to assess the effect of dynamic strengthening in improving dynamic patellar tracking among young females diagnosed with Patellofemoral Pain Syndrome.

Objectives:

Dynamic strengthening of quadriceps (VMO) on patellar tracking.

Method:

Total 10 young females with confirmed clinical diagnosis of PFPS were recruited as per selection criteria, all subjects were collected from Parul Sevashram Hospital. Patellar Tracking was measured using GaitON unit. The values derived from the Gaiton software are then used for the analysis and diagnosis of abnormalities in patellar tracking and its impact on joint mechanics.

Result:

The study revealed a significant reduction in patellar tracking deviations post-intervention, as indicated by the paired samples t-test ($p < 0.001$). The mean patellar tracking values improved from 3.99° pre-intervention to 2.53° post-intervention, with an average reduction of 1.46° . These findings suggest that targeted VMO strengthening effectively improves patellar stability in young females with PFPS.

Conclusion:

Dynamic strengthening of the vastus medialis obliquus significantly improves patellar tracking in young females with Patellofemoral Pain Syndrome. This study highlights the potential of structured VMO-targeted exercise protocols as an effective physiotherapy intervention for managing PFPS symptoms.

Keywords: Vastus medialis obliquus (VMO), Patellar tracking, Patellofemoral Pain Syndrome (PFPS), Dynamic strengthening, GaitON

INTRODUCTION**Anatomy of patellofemoral joint (PFJ)**

The patellofemoral joint is diarthrodial plane joint that consist of posterior surface of patella (kneecap) and trochlear surface of distal anterior femur (thigh bone), quadriceps muscles and articular cartilage. The patella, safeguarding the knee joint, moves within the trochlear groove of femur during activities. Quadriceps muscles including vastus medialis and vastus lateralis, connect the patella via quadriceps tendon essential for knee extension. Vastus medialis obliquus (VMO) played an important role in controlling the contact area and pressure distribution in PFJ. The patellar tendon extends from the patella to tibia, transmitting quadriceps forces. Articular cartilage covers joint surfaces, ensuring smooth movement⁽¹⁾. Vastus Medialis Oblique (VMO), a subset of the vastus medialis, runs obliquely and helps medially translate the patella. Its horizontal alignment makes it the primary medial stabilizer of the patella. Along with the vastus lateralis, the VMO aligns the patella within the trochlear groove during knee flexion and extension. Weakness or altered activity of the VMO can lead to patellar instability and pain⁽²⁾.

Biomechanics of patellofemoral joint

Biomechanics of patellofemoral joint delves into dynamic forces, muscle roles and elucidates the mechanics of patellar tracking, joint stability and the impact of muscle imbalances on patellofemoral kinematics⁽³⁾. The primary purpose of patella is to serve as a mechanical pulley for quadriceps as the patella changes the direction of extension force throughout knee range of motion. The patella is critical in last 30 degree of knee extension⁽⁴⁾. In the sagittal plane with knee in slight flexion, the apex of patella rest just at or slightly proximal to joint line.

Patellofemoral pain syndrome (PFPS)

Patellofemoral pain syndrome (PFPS) is the most common cause of knee pain. The term PFPS is often used interchangeably with anterior knee pain or runner's knee⁽⁵⁾

Person with PFPS commonly report symptoms of aching pain in retro patellar region which is increased with flexed knee postures such as during squatting, sitting, stair climbing or athletic activities⁽⁶⁾

Vastus medialis obliquus (VMO) activation during exercise, general quadriceps strengthening does benefit many patients with PFPS and is considered the gold standard treatment: The thighs and calves are frequently thought to be tight. PFPS is frequently the consequence of changing loads and modifications in the patella's weight-bearing capacity. Among the contributing elements are weakness in the legs and buttocks. lengthy sitting or driving, as well as frequent kneeling or bending. The gold standard treatment for PFPS is thought to be activating the vastus medialis obliquus (VMO) during exercise and strengthening the quadriceps generally⁽⁷⁾. Anterior knee discomfort that is localised behind or around the patella is a common presentation of PFS. Patients frequently struggle to identify the precise site of their discomfort. PFS is caused by a number of factors, such as muscle imbalance, trauma, overuse, and patellar malalignment.

Patellar tracking

The stability of patellofemoral joint involves dynamic and static stabilizers which control movement of patella within the trochlea, referred to as patellar tracking. Factors that may contribute to abnormal patellar tracking include quadriceps weakness, quadriceps muscle imbalances, hip weakness and altered foot kinematics. Static and dynamic stabilisers regulate the patella's movement inside the trochlea, a process known as patellar tracking, which contributes to the stability of the patellofemoral joint⁽⁵⁾. Affected foot kinematics, hip weakness, quadriceps weakness, and quadriceps muscle imbalances are some of the factors that might cause aberrant patellar tracking⁽⁷⁾. An imbalance in the dynamic interaction between the trochlea (femur groove) and the patella (kneecap) causes patellar maltracking⁽⁸⁾. Anatomical anomalies are frequently the cause of this illness. For the most part, PFS is a clinical diagnosis. Patients usually complain of anterior knee pain behind or around the patella. However, for some people, determining the precise location of pain might be difficult⁽⁹⁾. Among the symptoms are discomfort in the front of the knee that gets worse as you squat, jump, or go downstairs. knee-bending sensations such as popping, grinding, slipping, or catching. In extreme situations, the patella may dislocate entirely, resulting in excruciating pain and trouble walking. High knee stress (seen in sports involving twisting motions), muscle weakness, low tone, or structural abnormalities are risk factors.

PFPS and Q-angle

An anatomical measurement that represents the angle created by two lines is called the Q angle: a line that runs from the patella's centre to the anterior superior iliac spine (ASIS). a line drawn between the anterior tibial tuberosity's middle and the patella's centre⁽¹⁰⁾. It measures the lateral strain that the quadriceps muscles exert on the patella. PFPS may be more common in patients with a larger-than-normal Q angle (more than 20 degrees). The patella experiences more lateral forces when the Q angle is high. As a result, the patella has a tendency to track more laterally, or outside. Because of the increased pressure on these contact sites, pain in PFPS may be more noticeable on the exterior of the patella and femur⁽²⁾. Often atraumatic, it has been linked to increased weight bearing on the patellofemoral joint.⁽¹¹⁾

AIM

The aim of this research is to assess the effect of dynamic strengthening in improving dynamic patellar tracking among young females diagnosed with Patellofemoral Pain Syndrome.

OBJECTIVES

Dynamic strengthening of quadriceps (VMO) on patellar tracking.

HYPOTHESIS

H0: Null Hypothesis

- There is no significant effect of Dynamic strengthening for quadriceps (VMO) on patellar tracking.

H1: Alternative Hypothesis

- There is significant effect of Dynamic strengthening for quadriceps (VMO) on patellar tracking.

MATERIAL AND METHODOLOGY

Source of data: Parul SevaShram Hospital

Method of collecting data

- **Sample size:** 10
- **Sampling method:** Random Sampling
- **Study design:** Randomized Control Trial
- **Source of data:** Parul University
- **Study Population:** Young females with patellofemoral pain syndrome
- **Study duration:**
 - Total study duration – 1 year
 - Intervention duration – 6 weeks (4 days a week)

Inclusion criteria

- Young females aged 18-30 years of age.
- Participants with confirmed clinical diagnosis of PFPS made by orthopedic surgeon and/or Physiotherapist (McConnell Test, Fairbank's Apprehension Test and Patellofemoral Grind Test)
- Individuals who understand English/Hindi/Gujrati.
- Informed consent – Participants demonstrating their voluntary willingness to participate in the study they should understand study's objective, procedures potential risk and benefits.

Exclusion criteria

- Individuals with other associated significant knee conditions or pathologies such as Ligamentous Injuries, Meniscal Tear, Osteoarthritis, Cardiovascular, Pulmonary, Neurological or Musculoskeletal Condition that restricts them from doing exercises.
- Participants who are pregnant.
- Participants taking medications that may alter pain perception (example opioids, antidepressants) or interfere with neuromuscular control (example muscle relaxants)
- Participants receiving any other treatment that could influence the results the intervention.

Materials

- Assessment form
- Consent form
- Stool/chair
- Weight cuff (500 gm)
- TheraBand
- Bozu Ball
- Squeezable ball
- Barbell
- Weight Plates

Participants for research study were recruited from Parul Sevashram Hospital. A total 10 participants with confirmed clinical diagnosis of PFPS made by orthopedic surgeon or Physiotherapist were recruited for the study. Once recruited all the participants were screened using the assessment format (Appendix 2) including "McConnell test, Fairbank's apprehension test and Patellofemoral grind test". After screening the participants with PFPS were then assessed for inclusion and exclusion criteria. Participants falling into inclusion criteria were asked to sign the written consent form (Appendix 1).

Once the written consent form was signed, participants were assessed for baseline criteria and then were divided into two groups:

Dynamic Strengthening of quadriceps (vastus medialis obliquus) and gluteus maximus.

All the participants will be pre assessed for outcome measure before starting the intervention. Both the groups receive the treatment for total duration of 6 weeks as follows:

Transcutaneous electrical nerve stimulation (TENS)

- 4 electrodes

- Frequency – High (60-120 hertz)
- Duration of single pulse – 20-60 microseconds.
- Intensity is increased until the patient feels sharp tingling sensation.
- 4 treatment sessions per week, total of 6 weeks.

Patellar tracking for Q angle

- Placement of markers for analysis of Q angle –
 - Centre of the patella
 - Tibial tuberosity
 - Tip of distal second phalanx.

Exercise protocol

6 weeks protocol, 4 treatment sessions per week includes Straight leg raise (SLR), Abduction in side lying with 500gm weight, Abduction and lateral rotation with hip 30-degree flexion and knee 45-degree flexion, Knee extension, Squat, Forward lunge, Lateral band walks, One leg balance with knee flexion (on flat surface), Hip thrusts, One leg balance with knee flexion (on uneven surface), Barbell hip thrusts , Split squat, Single leg squat, Step up, Lateral step up, Diagonal step up, Forward hop, VMO strengthening.

RESULT

The aim of the study was to assess the effect of dynamic strengthening of the vastus medialis obliquus on patellar tracking in 10 young females with Patellofemoral Pain Syndrome. Patellar tracking was measured using GAITON software.

Table No. Age Distribution of the Data

Age Distribution	
Age	No. Of Participants
18-21	7
22-25	3
26-30	0

The age distribution of the 10 female participants showed that the majority (70%) were between 18-21 years, while 30% were aged 22-25 years, with no participants in the 26-30 years age group.

Graph No. Age Distribution of the Data

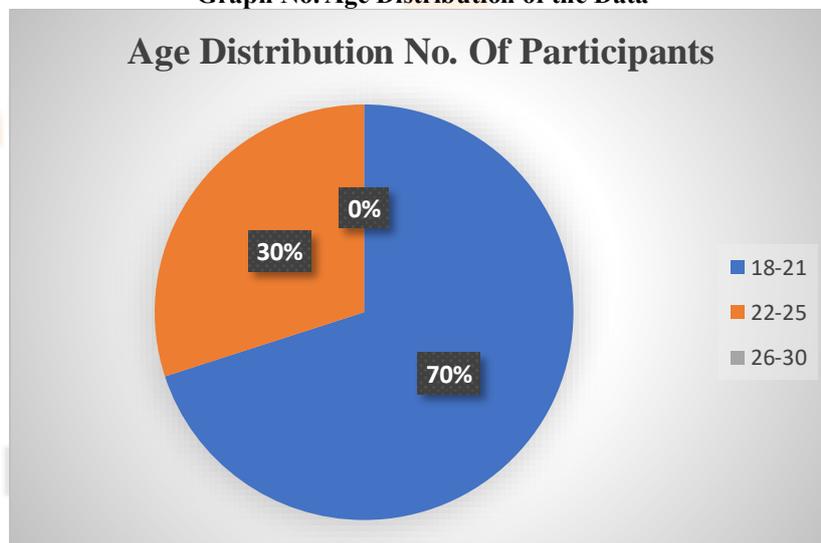


Table No. Descriptive Statistics of the Data

Descriptive Statistics					
		Minimum	Maximum	Mean	Std. Deviation
Age		18.00	24.00	20.20	1.99
Patellar Tracking (in degrees)	Pre	1.10	8.30	3.99	1.88
	Post	0.30	6.50	2.53	1.83

The descriptive statistics for the study participants indicate that the age of the 10 female participants ranged from 18 to 24 years, with a mean age of 20.2 ± 1.99 years. For patellar tracking measurements, the pre-intervention values ranged from 1.10 to 8.30 degrees, with a mean of 3.99 ± 1.88 degrees.

Post-intervention, the patellar tracking values showed improvement, ranging from 0.30 to 6.50 degrees, with a reduced mean of 2.53 ± 1.83 degrees. These results demonstrate a reduction in patellar tracking deviation following the dynamic strengthening intervention.

Graph No. Bar Diagram of Descriptive Statistics of the Data

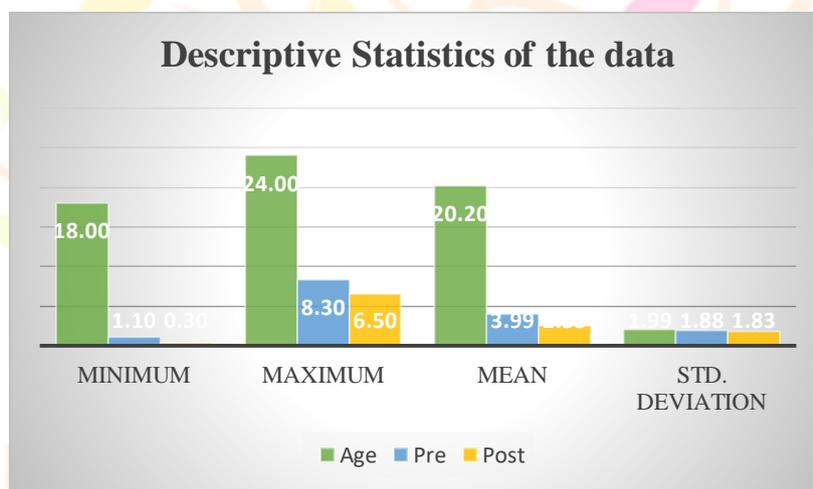


Table No. Intragroup Analysis (Comparison between pre and post treatment)

Paired Samples Test								
Patellar Tracking (in degrees)	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Post - Pre	-1.46	0.51	0.16	-1.83	-1.09	-9.01	9.00	0.00

A paired samples t-test revealed a statistically significant reduction in patellar tracking following the dynamic strengthening intervention ($t(9) = -9.01, p < 0.001$). The mean difference in patellar tracking between pre- and post-intervention measurements was -1.46 degrees (95% CI: -1.83 to -1.09), indicating an average improvement of 1.46 degrees in patellar tracking.

This finding provides strong evidence that the targeted VMO strengthening program effectively improved patellar stability in young females with Patellofemoral Pain Syndrome.

DISCUSSION

The purpose of this pilot study was to evaluate the impact of dynamic strengthening of the vastus medialis obliquus (VMO) on patellar tracking in young females diagnosed with Patellofemoral Pain Syndrome (PFPS). The significant reduction in patellar

tracking deviation from pre- to post-intervention provides substantial evidence supporting the efficacy of the targeted VMO strengthening protocol.

The age distribution of participants in this study reflects a range often associated with the highest prevalence of PFPS. A majority (70%) of participants were between the ages of 18 and 21, and the remainder were in the 22-25 age group.

The reduction in patellar tracking values, with pre-intervention measurements showing a mean of 3.99° and post-intervention values reducing to a mean of 2.53°, underscores the importance of VMO strengthening in addressing PFPS symptoms. The average improvement of 1.46° in tracking represents a clinically significant outcome. This change suggests that focused strengthening of the VMO mitigates the lateral tracking forces exerted by the vastus lateralis. These findings align with studies indicating that dynamic exercises designed to preferentially activate the VMO can restore the balance of forces necessary for optimal patellar movement during knee extension. (Yamamoto T, Nair P, Ma SW, Davis P, Yamamura HI, Vanderah TW, Porreca F, Lai J, Hruby VJ. *The biological activity and metabolic stability of peptidic bifunctional compounds that are opioid receptor agonists and neurokinin-1 receptor antagonists with a cystine moiety. Bioorganic & medicinal chemistry. 2009 Oct 15;17(20):7337-43.*)

Dynamic VMO strengthening exercises emphasize neuromuscular control and preferential muscle activation, often achieved through closed-chain exercises, biofeedback, or proprioceptive cues. Research has shown that such exercises effectively enhance VMO activation while minimizing vastus lateralis overactivation. A study by Bolgia and Earl (2008) demonstrated that incorporating targeted VMO activation into rehabilitation programs led to significant improvement in patellar alignment and reduced anterior knee pain in participants with PFPS.

In PFPS, an imbalance in this lateral-medial force dynamic causes maltracking, increased cartilage wear, and pain. VMO strengthening addresses these dysfunctions, promoting medial patellar stabilization (Powers et al., 2010). Biomechanical studies also highlight that neuromuscular control improves through repetitive activation of the VMO, reducing latency in its response during functional activities. This factor likely contributed to the enhanced patellar stability noted in post-intervention measurements.

The statistically significant difference in patellar tracking ($p < 0.001$) aligns with findings from prior research that demonstrated a consistent association between VMO strengthening and improved outcomes for PFPS. For example, Fukuda et al. (2010) evaluated a similar population and reported improvements in patellar tracking and reductions in pain scores following a six-week VMO strengthening protocol. The current study supports these findings by showing improvement after an intervention period. (Fukuda TY, Rossetto FM, MAGALHães ED, Bryk FF, Garcia Lucareli PR, de Almeida Carvalho NA. *Short-term effects of hip abductors and lateral rotators strengthening in females with patellofemoral pain syndrome: a randomized controlled clinical trial. journal of orthopaedic & sports physical therapy. 2010 Nov;40(11):736-42.*)

Moreover, studies by Crossley et al. (2002) have highlighted the importance of multimodal physiotherapy approaches, which include not only muscle strengthening but also stretching and biomechanical adjustments. While this study isolated the effects of VMO strengthening, future research could examine how combined modalities further enhance outcomes in this population. (Crossley K, Bennell K, Green S, Cowan S, McConnell J. *Physical therapy for patellofemoral pain: a randomized, double-blinded, placebo-controlled trial. The American journal of sports medicine. 2002 Nov;30(6):857-65.*)

The improvement observed in patellar tracking deviation after the intervention highlights the importance of VMO strengthening in the physiotherapy curriculum for PFPS management.

As clinicians, these results can guide treatment planning for young patients presenting with anterior knee pain and patellar instability. The simplicity and cost-effectiveness of dynamic VMO strengthening exercises also ensure broad applicability in clinical and community settings.

CONCLUSION

This pilot study demonstrates that dynamic VMO strengthening significantly improves patellar tracking in young females with PFPS, reducing deviation by 1.46°. These results emphasize the importance of targeted muscle strengthening in managing patellar maltracking and anterior knee pain. While the findings align with existing evidence, they pave the way for expanded research that explores the intervention's efficacy across diverse populations and integrated rehabilitation models.

By providing empirical support for the effectiveness of VMO strengthening exercises, this study underscores its potential as a cornerstone of physiotherapy for PFPS. Incorporating evidence-based protocols into routine practice can empower physiotherapists to deliver targeted, impactful care, ensuring improved quality of life for patients.

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Ethical approval - Ethical approval was obtained from The Institutional review board from Parul Institute of Physiotherapy, Waghodia, Vadodara.

Conflict of interest- None

Consent for publication- All individuals participating in this research signed an informed consent form prior to their inclusion in the study

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