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Research Article

Effectiveness of Quadriceps Flexibility and Vmo Strengthening Using Wall Ball Squats with Specific Exercises on Dynamic Patellofemoral Pain Syndrome in Athletes: An Observatonal Approach

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ABSTRACT

The primary objective of the present study is to evaluate the effectiveness of quadriceps flexibility and VMO Strengthening using wall ball squats with specific exercises on dynamic patella-femoral pain syndrome in athletes. Pre and post evaluation was performed on 15 participants using the VAS (Visual Analog Scale), Kujala Questionnaire Scale. Findings suggest Wall-ball squats offer a highly stable closed-chain position that minimizes anterior shear forces, promotes symmetrical co-contraction, and allows progressive loading without inducing excessive irritability. These characteristics likely facilitated smoother functional adaptation and higher overall performance scores. By offering controlled sagittal-plane strengthening, wall-ball squats may have better addressed the demands of functional mobility. Data suggest that the application of wall ball squats with specific exercises is effective intervention for treating dynamic patella-femoral pain syndrome in athletes.

Keywords: Patellofemoral Pain Syndrome (Pfps), Vas (Visual Analog Scale), Kujalaquestionnaire Scale.

INTRODUCTION

Patellofemoral Pain Syndrome (PFPS), also known as anterior knee pain or runner's knee(1) Patients with PFPS complain of pain behind or around the patella, which is normally vague, ill-localized, and may be dull or aching, but may also develop sharp pain in provocative positions. Functional activities that augment loading of the patellofemoral joint during knee flexion, such as running (especially downhill), squatting, lunging, descending or ascending stairs, kneeling, jumping, and prolonged sitting with flexed knees, (2,3,4)are known as the classical triggers of pain and are commonly called the theater sign. People can also report crepitus, stiffness after inactivity, instability or giving way, and, rarely, mild joint swellingwithout an actual effusion. Mechanical symptoms like locking or severe catching are abnormal and ought to trigger research on the other diagnoses. There are frequent functional limitations in which patients often reduce training or competitive performance due to pain during sport-specific movements(5).

PFPS may be divided into the types of its dynamics and statical types according to the mechanism which leads to the development of the malalignment of the patellar and the formation of the pain. PFPS in a non-weight-bearing or resting position has been identified to be ranked as static when it is anatomically influenced. These are inflated Q-angle, patella high or low, trochlear dysplasia, tibial torsion, excessive anteversion of the femur, length discrepancies in the lower limbs or abnormal foot position. The deviations of alignment are visible in the course of clinical examination and imaging in static PFPS and result in enduring changes in the mechanics of patellar contact that increases the load on the joint(6). Dynamic PFPS, on the other hand, is when there is normal-range static alignment, but abnormal lower-limb kinematics are manifested when the movement takes place. The neuromuscular impairments are the primary driving factors in this subtype, i.e., delayed or incomplete activation of the vastus medialis obliquus (VMO), imbalances in the quadriceps muscles, weakness of the hip abductors and external rotators, reduced trunk stability, and a lack of sensory-motor control(7,8). These deficits result in excessive internal rotation of the femur, adduction of the hips, collapse of the knee valgus during functional activities, and subsequent increase of the dynamic Q-angle and relative lateral movements and compression of the patella despite the absence of apparent structural malalignment. The more commonly seen type of PFPS is referred to as dynamic PFPS, which is especially linked with dysfunctional movement patterns during running, landing, cutting and squatting activities(9).

Exercise therapy is widely recognized as the cornerstone of conservative management and the most evidence-supported intervention for patellofemoral pain syndrome. Numerous randomized controlled trials and systematic reviews have consistently demonstrated that targeted strengthening programs combined with neuromuscular retraining significantly reduce pain intensity and improve functional performance in individuals with PFPS. Contemporary rehabilitation paradigms emphasize the preferential use of closed kinetic chain (CKC) exercises because they impose more physiologically appropriate joint loading and better replicate the movement patterns encountered during sporting activity. CKC exercises engage multiple joints simultaneously, stimulating co-contraction of muscle groups spanning the hip, knee, and ankle, thereby enhancing coordination across the entire kinetic chain and improving dynamic joint stability. Importantly, clinical trials consistently show that combined hip and knee strengthening programs are superior to isolated knee strengthening alone for pain reduction, functional improvement, and return-to-activity outcomes. These findings highlight the critical role of proximal neuromuscular control, especially hip abductor and external rotator strength, in minimizing femoral internal rotation, knee valgus alignment, and lateral patellar tracking during dynamic tasks—key pathological mechanisms underlying PFPS(10).

Wall-based squat exercises, typically performed with a therapy ball positioned between the lumbar spine and a wall surface, are frequently prescribed in PFPS rehabilitation due to their ability to provide controlled, repeatable knee loading while promoting optimal sagittal-plane posture. The ball support assists in maintaining neutral trunk alignment, reducing forward trunk lean, controlling excessive anterior tibial translation, and minimizing undesirable knee stress, particularly in patients with limited motor control or high pain sensitivity. This positioning enables safe performance of progressive knee flexion while sustaining consistent quadriceps activation and patellar alignment. Institutional rehabilitation protocols from high-volume orthopedic centers and sports medicine guidelines consistently list wall squats, wall slides, and partial squat exercises as first-line strengthening strategies in the early-to-mid rehabilitation phases for PFPS, often alongside step-ups, step-downs, and lunge progressions(12,13).

Due to the rising number of competitive and recreational athletes suffering with PFPS, and inconsistency of existing research on optimal exercise choice, and lack of research studies in athletic populations, studies assessing functional rehabilitation interventions specifically aimed at dynamic PFPS are urgently needed. The proposed research aims to fill this gap directly by Observe the impact of quadriceps flexibility and VMO strengthening when performed on the wall ball squats combination with exercises on pain, neuromuscular performance and functional outcomes in athletes. Through determining effectiveness with regard to providing better biomechanical correction and symptom relief, this study will add significant evidence to the optimization of sport-specific rehabilitation regimes, enhanced treatment efficacy, faster safe sport participation, and reduced recurrence of PFPS**.**

Aim & Objectives of the Study

To evaluate the effect of wall ball squats combined with therapeutic exercises on:

- Quadriceps flexibility,
- VMO strengthening and neuromuscular activation,
- Pain intensity,
- Functional knee performance in athletes with dynamic PFPS.

MATERIALS AND METHODOLOGY

The cross sectional research design was used in study. A cross sectional study is a sort of observational study in which data is collected at a single moment in time to evaluate the relationship between variables. The study used

randomized sampling as its sample design. The participants (athletes) were affected with dynamic patella-femoral pain syndrome. These individuals were involved in the study to see how wall ball squats with specific exercises program affected their condition.
Paper and pencil for data recording, chair for participants to sit on during assessment and treatment, a treatment couch, swiss-ball, assessment form, consent form, towel for comfort or support were all used in the study.

Selection Criteria:
Inclusion Criteria:

- Both males and females
- Age -18 to 40 years
- presence of the anterior knee pain for a period in excess of 6 months.
- knee pain when climbing stairs.
- knee pain during squatting, kneeling
- lengthy sitting, hopping and jumping
- lifting heavy weights

Exclusion Criteria:

- Subluxation
- No previous knee surgery
- Knee disorder other than PFP
- Recurrent patella
- Clinical evidence of meniscus and ligaments lesion and patella tendon pathology
- Any neurological disease
- History of diabetes

Sample Size and Study Duration
For this study the sample size was 15 people the individual were chosen at random from the research population to ensure representativeness and adequate data for analysis. The Study was carried out (3 times a week) for six weeks, individuals in a clinical environment had therapy as part of the study in pacific college of physiotherapy, department of physiotherapy (PMCH) pacific medical university (Udaipur), after obtaining ethical committee approval dated 6-10-2025, PMU/IEC/MPT/2025. All participants completed information and consent form at recruitment. This time frame allowed for evaluation of subjects response to the therapy as well as any changes in their pain, range of motion and functional ability. Each session was scheduled for 40-45 minutes. This period was set aside to ensure the patient had enough time to execute the procedure correctly.

Procedure
Permission for conduct of research is taken from the institutional ethical committee of PMCH, (**Protocol no. PMU/IEC/MPT/2025**) Pacific medical university bhilo ka bedla Udaipur(RAJ).
Athletes Diagnosed with Patellofemoral Pain Syndrome (PFPS) by the Physiotherapy department, Orthopedic department OPD; initially assessed for the inclusion or exclusion criteria. Prior to the treatment procedure, all participants were informed about the purpose, procedures, potential benefits, and possible risks of the study. Written informed consent was obtained from each participant prior to enrollment.
15 subjects were selected on the basis on inclusion criteria treated with wall ball squats with specific exercises.

Exercise	Position / Equipment	Procedure / Technique	Hold Duration	Repetitions & Sets / Duration	Progression / Focus
Quadriceps Stretching	Standing	Heel pulled toward buttocks until anterior thigh stretch is felt	30 seconds	3 reps × 2 sets	Maintain flexibility; reduce anterior thigh tightness
Wall Ball Squats	Standing; 20 cm diameter ball between lower back and wall	Slow squatting to 90° knee flexion while maintaining ball contact; emphasize controlled movement	— (Dynamic)	10 reps × 3 sets	Focus on VMO activation during terminal knee extension

Component	Procedure / Technique	Hold Duration	Repetitions / Duration	Focus / Purpose

Isometric VMO Contractions	Tighten VMO without moving knee; maintain patella alignment	5–10 sec hold	10–15 reps	Increase VMO activation & medial knee stability
Step-Downs	Controlled step-down while maintaining knee over second toe	Dynamic	10–12 reps × 2–3 sets	Improve eccentric quadriceps control &neuromuscular coordination
Static Lunges (No Resistance)	Stationary lunge ensuring hip–knee–ankle alignment	2–3 sec hold	10 reps × 2–3 sets	Strengthen quadriceps & improve functional stability
Neuromuscular Training Block	Combination of above exercises performed as a circuit	—	10–15 minutes per session	Enhance motor control, balance & functional knee

RESULTS

A total of 15 participants were included in the study, 5 females and 10 males. Participants had a mean age of **27.4 years** with a smaller standard deviation of **2.5**, demonstrating more uniformity in age distribution, ranging from **23 to 32 years**.

Table 1 Analysis of the Trends in the VAS Scale over Time (DAY 1, 3RD WEEK, 5TH WEEK)

	Day 1	**3rd Week**	**5th Week**
Mean	8.6	6.067	1.133
Std. Dev.	0.74	0.99	1.28
Median	9	7	4

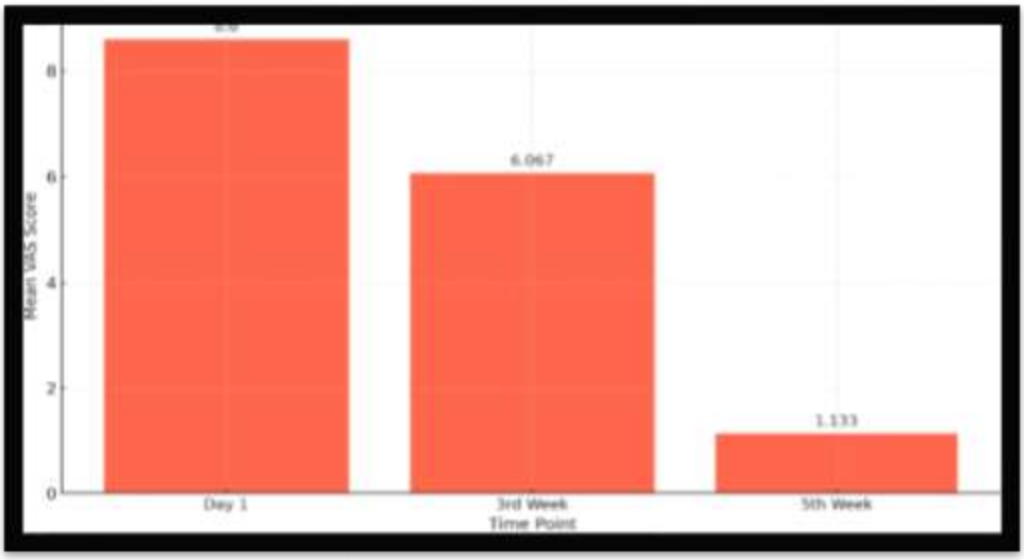

Table & Graph 1 presents the pain progression of participants. The mean VAS score was 8.6 on Day 1, which decreased to 6.067 by the 3rd Week and sharply dropped to 1.133 by the 5th Week. Which shows a dramatic pain decline by Week 5, almost reaching minimal pain levels. The shift in median values (9 → 7 → 4) also reinforces a strong pain reduction trend. This suggests that ball squats, despite placing some patellofemoral load initially, eventually contribute significantly to pain relief as functional control improves. Standard deviations remained stable, showing consistent responses across participants.

Participants showed slower initial pain relief but exceptional improvement by Week 5, likely due to enhanced neuromuscular stability, better lower-limb alignment, and improved eccentric control developed through ball squats. This shows that functional multi-joint exercises can also meaningfully reduce pain when combined with proper neuromuscular cues.

Table 6 Analysis of the Trends in the KUJALA Scores over Time (DAY 1, 3RD WEEK, 5TH WEEK)

	Day 1	3rd Week	5th Week
Mean	71.933	73.867	88.2
Std. Dev.	0.88	2.11	2.18
Median	71.5	74	79

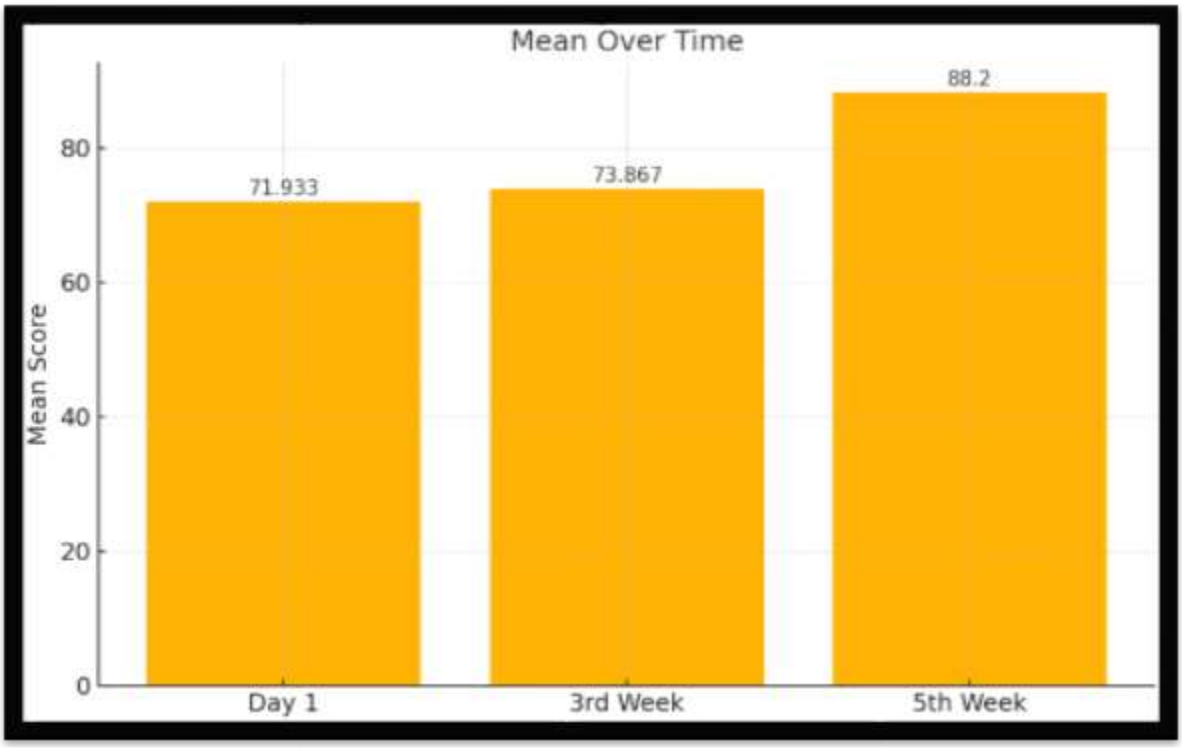

Table & graph 2 highlights strong functional improvements. Mean Kujala scores improve from 71.933 on Day 1 to 73.867 in Week 3 and dramatically to 88.2 by Week 5, indicating superior functional restoration. The substantial Week 5 increase shows that ball squats effectively enhance proprioception, stability, and coordinated hip–knee mechanics essential for athletic tasks. Median values (71.5 → 74 → 79) also demonstrate consistent upward progression.

Participants demonstrated remarkable improvement in functional ability, indicating that wall-ball squats, along with supplementary neuromuscular exercises, strongly enhance knee joint performance. Activities requiring coordination, endurance, and stability are better trained by squat-based interventions, explaining superior outcomes.

From the summarized table and graphs, we can make the following observations:

The mean VAS scale scores for pain intensity (KUJALA) decrease over time for both males and females. This suggests that the therapy (BALL SQUAT) has a positive effect in reducing pain.

DISCUSSION

The present study was design to examine the effects of wall ball squats with specific exercises, in athletes affected with Patellofemoral Pain Syndrome (PFPS). A total of 15 patients were included and assessed using pre- and post-intervention outcome measures. The outcome measures used were the VAS (Visual Analog Scale), KujalaQuestionnaire Scale. The findings suggest a significant reduction in pain level and improvement in functional abilities following the intervention.

Wall-ball squats, although less dynamically complex, have demonstrated strong clinical applicability in early to mid-stage PFPS rehabilitation due to their ability to maintain controlled load progression. When performed with a ball support, the exercise reduces patellofemoral compressive forces, assists individuals in maintaining neutral alignment, and allows adjustments based on pain tolerance. These characteristics make wall-supported squats particularly suitable for patients with high irritability or reduced tolerance to high-demand tasks. Numerous clinical guidelines and consensus statements recommend wall-ball squats for foundational strengthening because they facilitate coactivation of the hip and knee musculature without requiring advanced neuromuscular control. However, comparative studies have suggested that exercises incorporating additional postural challenge - such as semi-squats with isometric hip adduction, perturbation-based lunges, or variations that increase proprioceptive input - may yield enhanced functional gains. This is echoed by Mahmood et al., who found superior improvements when hip-adduction resistance was added to CKC exercises, and by Earl & Hoch, who observed better functional outcomes when neuromuscular and proprioceptive demand was increased.

Taken together, the literature indicates a gradient of therapeutic benefit across CKC exercises, where stability-focused strengthening offers foundational improvements, but dynamic, multi-planar movements tend to generate more profound neuromuscular and functional adaptations. The present study's therefore aligns directly with this evolving evidence base and enriches current understanding by evaluating how these contrasting CKC strategies perform within an athletic PFPS population- a group for whom optimized dynamic control and functional efficiency are essential.

Further critical analysis of past research shows that although numerous interventions have focused on strengthening, neuromuscular activation, or proprioceptive training individually, very few studies have evaluated these components in conjunction with quadriceps flexibility, despite strong biomechanical evidence linking quadriceps tightness to altered patellofemoral mechanics and symptomatic maltracking. Quadriceps tightness increases patellofemoral compressive forces, restricts knee flexion mechanics, and contributes to lateral patellar drift - yet flexibility is often overlooked when designing strengthening protocols. Moreover, although VMO-specific EMG research, NMES-based activation trials, proprioceptive training interventions, and hip-dominant strengthening RCTs each provide valuable insight into specific mechanisms of PFPS, these studies typically investigate one isolated domain rather than the interactive effects of pain, flexibility, neuromuscular timing, and functional performance. Consequently, the present study offers a novel contribution by assessing all these variables collectively, providing a more holistic understanding of how closed-chain interventions influence multiple PFPS-related impairments simultaneously. This approach aligns with the integrated neuromuscular model outlined by Alsaleh (2025), who identified delayed VMO onset, reduced torque production, impaired rate of force development, and hamstring tightness as hallmark neuromuscular deficits in PFPS. When interpreted together, these findings reinforce the importance of interventions that simultaneously improve quadriceps length, neuromuscular balance, and functional load tolerance, to observe wall-ball squats with specific exercise program particularly meaningful.

When the aims of the present study are examined in the context of the broader literature, wall-ball squats are strongly supported for their ability to provide controlled activation with reduced patellofemoral stress, making them especially useful during early-stage rehabilitation or for individuals with high irritability. They facilitate foundational strength-building, encourage proper hip–knee coactivation, and allow pain-modulated progression in a manner that is both safe and clinically practical.

CONCLUSION

The findings of the study suggests that wall-ball squats would produce greater functional gains. Functional tasks assessed through the Kujala questionnaire - such as stair climbing, squatting, walking, jumping, and prolonged sitting tolerance - depend heavily on controlled loading, endurance, and coordinated movement efficiency. Wall-ball squats offer a highly stable closed-chain position that minimizes anterior shear forces, promotes symmetrical co-contraction, and allows progressive loading without inducing excessive irritability. These characteristics likely facilitated smoother functional adaptation and higher overall performance scores.

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