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Research Article

A Comparative Study to Analyze the Influence of Quadriceps Flexibility and Vmo Strengthening Using Lunges with Resistance Band Versus Wall Ball Squats With Combined Exercises on Dynamic Patellofemoral Pain Syndrome in Athletes

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ABSTRACT
Background: Patellofemoral syndrome (PFS), or alternatively referred to as patellofemoral pain syndrome (PFPS) or "runner knee syndrome is one of the most common causes of anterior knee pain in clinical and sports medicine practice. It is noted by diffuse, ill-localised pain around or behind the patella, which is usually exacerbated by knee loading exercises in flexed position like running, climbing stairs, squatting, and sitting. Clinical tests focus on posture, alignment, bulk of the muscles (e.g., vastus medialis atrophy), local tenderness, range of movement, and strength of the quadriceps and hip muscles. The PFS treatment is largely conservative and aims to manage pain, repair biomechanical dysfunction, and restore function. The first line of treatment consists of activity modification, temporary use of non-steroidal anti-inflammatory drugs (NSAIDs), and modalities such as ice to relieve symptoms during the acute stage. Nevertheless, structured rehabilitation programs are most often associated with long-term improvement. The therapeutic exercise geared toward enhancing strength, flexibility, and neuromuscular control of the knee and hip has always been found to be the most effective. In this study resistance-band lunge training and wall ball squats combined with therapeutic exercises has been introduce to reduce pain and improve function.
Objective: The objective of the study is to i) evaluate the effect of resistance-band lunge training, ii) evaluate the effect of wall ball squats combined with therapeutic exercises, iii) compare the outcomes between the two intervention programs to determine which approach is more effective.
Methods: 30 athletes diagnosed with the patellofemoral pain syndrome (PFPS) by orthopedic OPD or physiotherapy department were initially assessed for the inclusion or exclusion criteria. Prior to the treatment procedure patient are oriented to the study. Participants are divided into 2 groups and both groups assessed for the pre test parameter.
Outcome measure: VAS (Visual Analog Scale), and Kujala Questionnaire Scale is used for measuring pre and post intervention evaluation.
Results: The results illustrate that pain reduction and functional improvement do not always follow the same trajectory, and different exercise strategies may target different aspects of patellofemoral pain syndrome. Thera-band lunges proved to be an excellent choice for rapidly reducing pain, while wall ball squats and associated neuromuscular exercises were more effective for developing overall functional capabilities needed for sports and higher-level activities. Although both groups improved, the study's outcomes suggest that an optimal rehabilitation approach may blend elements from both interventions-using pain-reducing strategies early on and gradually transitioning into functional strengthening and neuromuscular control exercises as pain subsides.
Conclusion: The findings of the present investigation clearly demonstrate that both interventions produced substantial improvements in pain and functional outcomes by the end of the intervention period.

Keywords: Patellofemoral Pain Syndrome (PFPS), VAS (Visual Analog Scale), Kujalaquestionnaire Scale.

INTRODUCTION

Patellofemoral syndrome has become one of the biggest burdens with regard to epidemiology in active populations. In sports medical practice, it can explain about a quarter up to nearly two-fifths of all complaints related to the knee. It is notably predominant among the teens and young adults, and more so in females and can be over 20 percent in certain adolescent cohorts. This prevalence is a significant one and hence the importance of this condition as a major cause of activity limitation and decreased sports participation(1).

PFS is primarily a clinical diagnosis based on a thorough history and physical examination. There is also a risk of patients having either unilateral or bilateral symptoms and the development of either a gradual onset or an acute exacerbation associated with changes in training(2,3,4,5).Pain is said to be aching, but may be sharp on loading, and may be associated with giving way or catching sensations, which require pain to be carefully differentiated with ligamentous or meniscal injuries. Clinical tests focus on posture, alignment, bulk of the muscles [(6)](e.g., vastus medialis atrophy), local tenderness, range of movement, and strength of the quadriceps and hip muscles. Special tests are less specific and sensitive; hence, they are viewed within the overall clinical setting(7,8,9,10). Imaging is typically used when conservative management fails after several weeks and is chiefly aimed at ruling out other structural pathologies. The symptoms of typical PFS have limited correlation with routine radiographs and advanced imaging(11,12,13).

The PFS treatment is largely conservative and aims to manage pain, repair biomechanical dysfunction, and restore function. The first line of treatment consists of activity modification, temporary use of non-steroidal anti-inflammatory drugs (NSAIDs), and modalities such as ice to relieve symptoms during the acute stage(14,15,16,17,18). Nevertheless, structured rehabilitation programs are most often associated with long-term improvement. The therapeutic exercise geared toward enhancing strength, flexibility, and neuromuscular control of the knee and hip has always been found to be the most effective. The exercise regimens normally focus on strengthening of the quadriceps (particularly, vastus medialis obliquus), hip abductor and external rotator muscles, and the tight muscle group stretching. Adjunctive therapies, including patellar taping, could provide added pain relief and exercise adoption, but their efficacy could be affected by other variables, including body mass index(19).

In general, prognosis of PFS is usually good with a large percentage of patients responding to conservative rehabilitation and home exercise program. Nevertheless, a considerable proportion of them still have persistent symptoms at one year and some of them can have persistent symptoms over a number of years. Poor patellar tracking and unremedied biomechanical defects can predispose to long-term outcomes such as patellofemoral osteoarthritis and persistent activity-related pain(20,21,22).Given this, it is important to optimize evidence-based, exercise-based rehabilitation approaches, especially within the sporting community, to achieve better results, reduce recurrence, and enable a quicker return to sport(23).

Two of the most widely recommended closed kinetic chain modalities used in PFPS rehabilitation include resistance-band lunges and squat based combined exercise programs that involve the use of a wall ball. Both treatments are meant to enhance strength of the quadriceps, neuromuscular control, and activation of VMO, and dysfunction of the kinetic-chain. Their mechanisms of therapy, however, are very different. The resistance-band lunges are dynamic multiplanar stabilization, frontal-plane knee and hip, higher proprioceptive input and closely related sporting motion like cutting, deceleration, and one-leg landing. On the other hand, wall ball squats provide a controlled environment of strengthening and limiting excessive stress on the joints whilst allowing progressive loading of the quadriceps with constant training to maintain patellofemoral alignment and combine proximal and distal kinetic-chain exercises. Although the use of both methods is justified by the literature independently, there is no direct quality evidence that helps determine which method would be more effective in terms of enhancing the clinical outcomes among athletes with dynamic PFPS.

Lunges represent a prototypical functional CKC exercise characterized by multiplanar, multi-joint motion that requires integrated activation of the quadriceps, hamstrings, hip extensors,

hip abductors, and trunk stabilizers under weight-bearing conditions. During performance of a forward or multi-directional lunge, the lead limb undergoes controlled eccentric quadriceps activation for deceleration and shock absorption, followed by concentric loading onto knee and hip extensors for propulsion. Resistance band augmentation increases the therapeutic stimulus by introducing external frontal-plane loading forces that challenge the athlete to maintain proper knee–hip alignment. Depending on band placement, lateral forces applied at the knee or pelvis increase the recruitment demands on medial knee stabilizers such as the Vastus Medialis Obliquus (VMO) and proximal stabilizers including the gluteus medius and deep hip external rotators(25).

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(26,27).

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, comparative studies assessing functional rehabilitation interventions specifically aimed at dynamic PFPS are urgently needed. The proposed research aims to fill this gap directly by comparing the impact of quadriceps flexibility and VMO strengthening when performed on resistance bands during lunges versus when performed on the wall ball squats versus when performed in combination with exercises on pain, neuromuscular performance and functional outcomes in athletes. Through determining which method is most effective 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.

MATERIAL & METHOD

Study Design: Comparative study

Sample Design: Simple random sampling

Sample Size: 30 Patient will be randomized selected and Will be assessed for the pre-test parameter.

Study Setting: Patient were treated 3 times per week on 3 separate days for 5 week at Department of physiotherapy, Pacific Medical college and hospital. UDAIPUR

Study Population: Athlete with Patello-femoral pain syndrome, both male and female participants are included.

Study Duration: one year

Sample Size: 30 participants

Treatment Duration: single session 45-60 minutes for (3 days per week) for 5 weeks. The data will be collected on day 1, at the end of the 3rd week & at the end of the 5th week. For both groups above, interventions were given 3 times a week on 3 separate days for 5 weeks.

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

Procedure

Permission for conduct Study 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 the patella-femoral 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. Following the consent process, the participants were randomly allocated into two groups.

30 subjects will be selected on the basis on inclusion criteria and will be randomly divided into Group-A and Group B.

- Group A (n=15)**:** Lunges with resistance band (TheraBand) and quadriceps stretching
- Group B (n=15)**:** Wall ball squats with combined exercises and quadriceps stretching

Group A:

Exercise	Position / Equipment	Procedure / Technique	Hold Duration	Repetitions & Sets
Quadriceps Stretching	Standing	Participant holds ankle of affected limb and pulls heel towards buttocks until stretch is felt in anterior thigh	30 seconds	3 reps × 2 sets
VMO Strengthening using Resistance Band Lunges	Standing; Blue TheraBand (0.21 N/nm) tied around back foot and anchored	Forward lunges with strict knee alignment; patella tracks over second toe; controlled eccentric and concentric motion	— (Dynamic exercise)	10 reps × 3 sets

Group B:

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

Combined Exercises (Group B)

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

DATA ANALYSIS AND RESULTS

The findings of this study show that both rehabilitation approaches were effective in helping athletes with dynamic patellofemoral pain syndrome experience meaningful improvements in their symptoms and knee function over the 5-week intervention period. However, each intervention demonstrated different strengths. The Theraband-based VMO strengthening program used in Group A appeared to work particularly well for reducing pain. In contrast, the wall ball squat–based functional training program used in Group B, which also included neuromuscular control exercises, led to greater enhancement in overall knee function.

When examining pain levels through VAS scores, both groups began the study with nearly identical pain intensities—Group A at 8.8 and Group B at 8.6—showing that neither group had an advantage at baseline. By the third week, both groups had reduced pain noticeably, but the difference between them was still not statistically meaningful, suggesting that early improvements can be attributed to general therapeutic effects common to both interventions. By the fifth week, however, the results clearly diverged. Group A reported a dramatic reduction in pain scores, reaching a mean of 1.133, whereas Group B showed a mean of 2.867. This difference was statistically significant, demonstrating that the Theraband lunge protocol was more effective in easing pain—likely due to its emphasis on controlled VMO activation, improved patellar tracking, and reduced anterior knee stress during movement.

In contrast, the Kujalascore analysis revealed a different pattern of recovery focused on function rather than pain. Both groups started at similar functional levels, but by the fifth week Group B displayed a greater overall functional improvement. Group B achieved a mean Kujalascore of 88.2, compared to 78.8 in Group A, and this difference was statistically significant. This suggests that wall ball squats, which require coordinated hip–knee–ankle control, enhance neuromuscular stability and functional performance more effectively than the Theraband lunges alone. The additional combined exercises in Group B (such as step-downs and isometric VMO holds) also likely contributed to improved dynamic control and knee alignment during functional tasks.

Table 1 – Age Distribution of Participants

Group	n	Mean Age (years)	SD	Minimum	Maximum
Group A (Theraband)	15	25.6	4.6	20	34
Group B (Ball Squat)	15	27.4	2.5	23	32

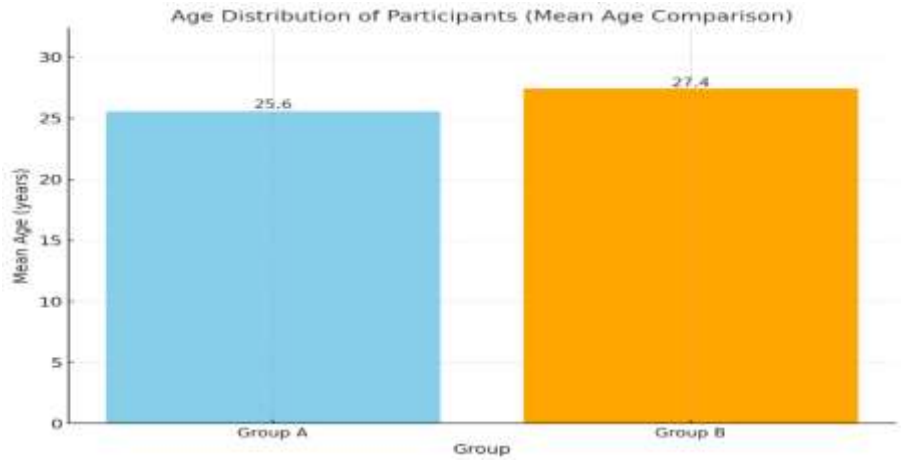


Table 2– Gender Distribution of Participants

Gender	Group A (Theraband) n (%)	Group B (Ball Squat) n (%)
Male	11 (73.3%)	10 (66.7%)
Female	4 (26.7%)	5 (33.3%)
Total	15 (100%)	15 (100%)

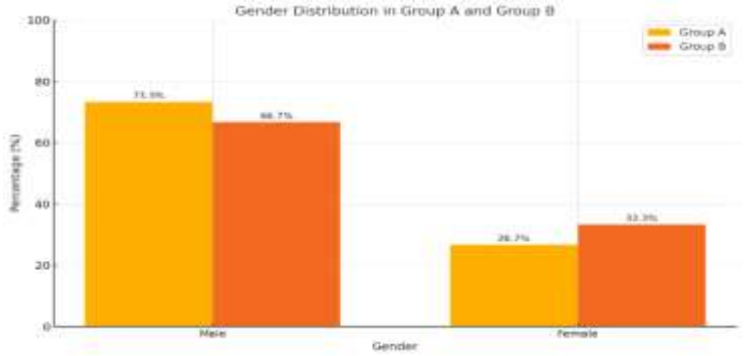


Table 3 Analysis of the Trends in the VAS Scale over Time (DAY 1, 3RD WEEK, 5TH WEEK)

	Day 1	3rd Week	5th Week
Mean	8.8	4.267	2.867
Std. Dev.	0.63	0.96	1.15

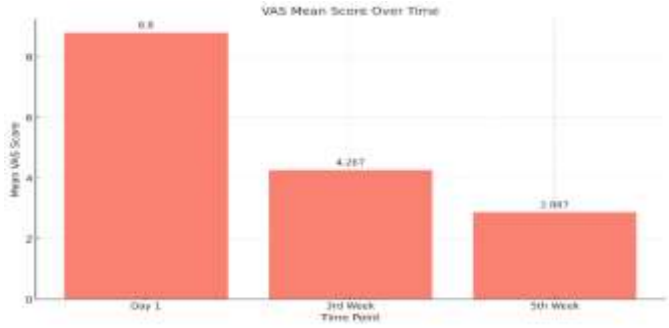
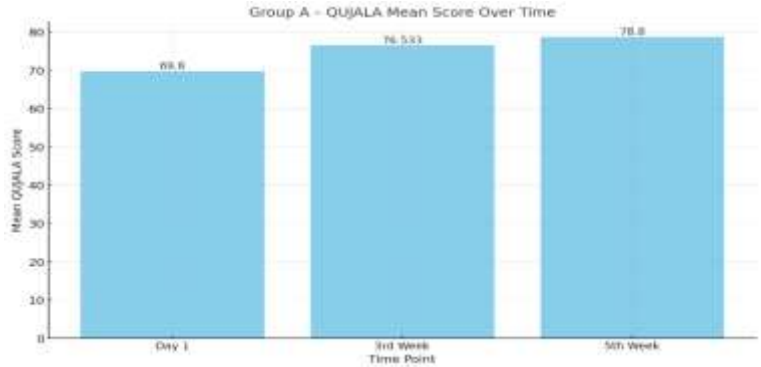


Table 4 Analysis of the Trends in the KUJALA Scores over Time (DAY 1, 3RD WEEK, 5TH WEEK)

	Day 1	3rd Week	5th Week
Mean	69.8	76.533	78.8
Std. Dev.	0.94	3.62	2.88



Group B

Table 5 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

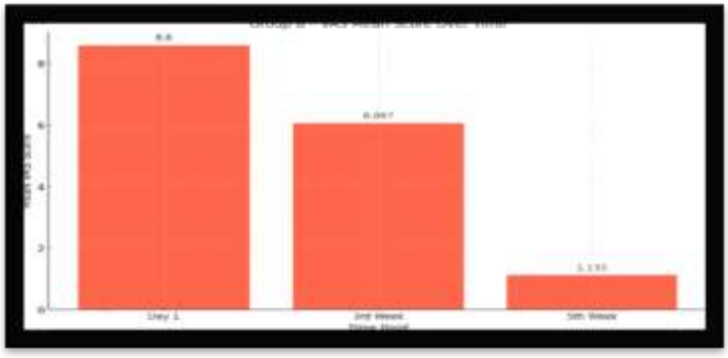


Table 6 Analysis of the Trends in the KUJALA Scores over Time (DAY 1, 3RD WEEK, 5TH WEEK)

	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

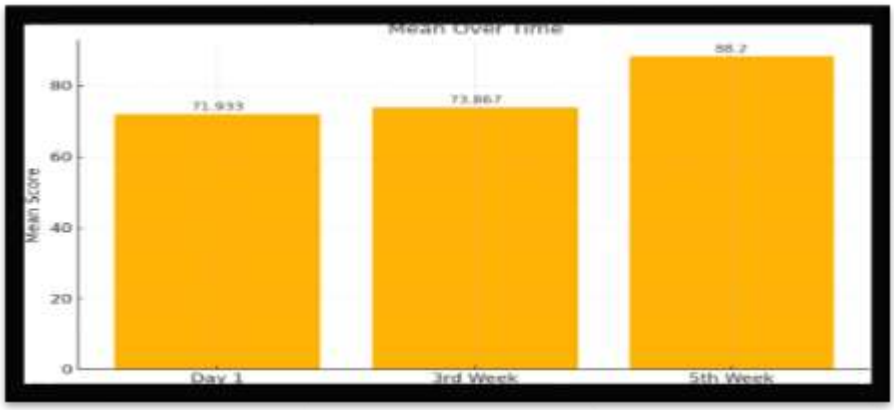


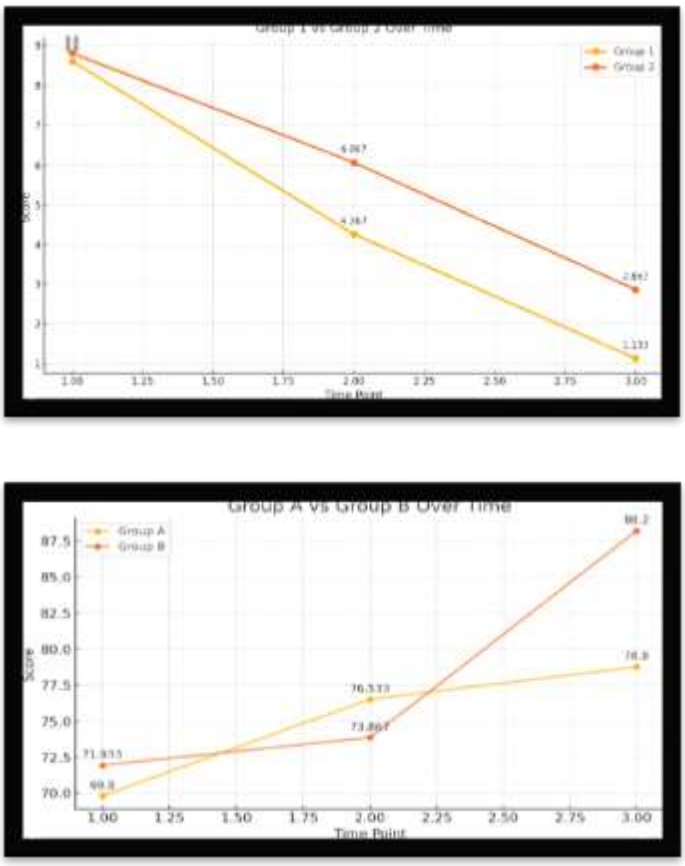
Table 7: Comparison of Mean VAS Scale and KUJALA Scores between Group a (Theraband) and Group B (Ball Squat)

Variable	**Group A (TheraBand)**	**Group B (Ball Squat)**	**t-value**	**p-value**	**Interpretation**
VAS Scale (Day 1)	8.8	8.6	0.200	0.842	No significant difference
VAS Scale (3rd Week)	4.267	6.067	-1.615	0.117	No significant difference
VAS Scale (5th Week)	1.133	2.867	2.239	0.034	Significant difference (Theraband more effective)
KUJALA(Day 1)	69.8	71.933	-1.564	0.128	No significant difference
Kujala (3rd Week)	76.533	73.867	1.008	0.321	No significant difference

Kujala (5th Week)	78.8	88.2	-2.814	0.009	Significant difference (Theraband more effective)

Time Point: 1-Day 1, 2-3rd Week, 3-5th Week

Graph 6: Comparison of Mean KUJALAScores between Group A and Group B



DISCUSSION

The present study was designed to compare the effectiveness of two widely implemented closed-kinetic chain rehabilitation strategies—resistance-band lunges combined with quadriceps stretching and wall-ball squats supplemented with additional functional exercises—in reducing pain, improving quadriceps flexibility, enhancing VMO activation, and restoring overall functional performance among athletes experiencing dynamic patellofemoral pain syndrome (PFPS). The rationale for this investigation stems from the contemporary understanding that PFPS is not a single-structure pathology but a complex, multifactorial disorder shaped by interrelated impairments across the lower-limb kinetic chain. Key contributing factors such as quadriceps tightness, deficits in neuromuscular timing (particularly delayed VMO activation relative to the VL), altered hip–knee alignment, compromised movement coordination, and reduced functional stability all increase patellofemoral joint stresses and aggravate symptoms during athletic activity. These mechanisms have been repeatedly documented across biomechanical, neuromuscular, and clinical studies, forming the conceptual framework that guided the current research.

Extensive literature consistently supports the view that successful PFPS rehabilitation must incorporate interventions that target both proximal (hip musculature) and distal (quadriceps and patellar mechanics) contributors to patellofemoral dysfunction. Research by Nascimento et al.[16]and Manojlovićet al. [7]has demonstrated that strengthening programs integrating both hip and knee musculature produce superior improvements in pain, activity levels, and functional performance compared to knee-focused exercises alone. Similarly, Santos et al.

and Winters et al. emphasized in their systematic reviews and meta-analyses that multimodal strengtheningparticularly including hip abductors, external rotators, and quadriceps—is the cornerstone of evidence-based PFPS management. This body of work highlights the importance of choosing rehabilitation strategies that correct biomechanical faults while simultaneously improving neuromuscular control, load tolerance, and movement quality.

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 mal tracking. 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 makes a novel contribution by assessing these variables collectively, providing a more holistic understanding of how closed-chain interventions simultaneously influence multiple PFPS-related impairments. 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, making the head-to-head comparison between resistance-band lunges and wall-ball squats particularly meaningful.

When the aims of the present study are examined in the context of the broader literature, resistance-band lunges appear theoretically advantageous due to their inherent demands on dynamic stabilization, multi-planar control, active VMO engagement, and high-level neuromuscular coordination. These characteristics make such exercises highly relevant for athletic movements requiring deceleration, directional changes, single-leg control, and rapid load absorption. In contrast, 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 co-activation, and allow pain-modulated progression in a manner that is both safe and clinically practical.

Therefore, contrasting these two interventions addresses an important gap in PFPS rehabilitation research, particularly within athletic populations where both flexibility restoration and advanced neuromuscular refinement are essential for return to high-demand activities. The reviewed literature supports the present study's objective by showing that no single CKC exercise model optimizes all PFPS impairments; rather, different exercises may target distinct deficits. The integration of these findings with the study's rationale suggests that while both interventions are theoretically valid, resistance-band lunges are likely to provide superior neuromuscular recruitment, proprioceptive challenge, and sport-specific carryover, whereas wall-ball squats may excel in producing controlled strength gains and symptom reduction during foundational phases. Together, this comprehensive analysis underscores the significance of the current investigation and highlights its unique contribution to evolving PFPS rehabilitation strategies by identifying context-driven exercise selection rather than a one-size-fits-all approach.

CONCLUSION

The present study was undertaken to compare the therapeutic effectiveness of two widely practiced closed-kinetic chain rehabilitation approaches—resistance-band lunges combined with quadriceps stretching and wall-ball squats supplemented with combined exercises—in athletes experiencing dynamic patellofemoral pain syndrome (PFPS). The findings of the present investigation clearly demonstrate that both interventions produced substantial

improvements in pain and functional outcomes by the end of the 5-week intervention period. This aligns with abundant evidence in the PFPS literature showing that closed-kinetic chain exercises—which emphasize co-contraction of hip and knee musculature, load-sharing, and dynamic stability—are particularly effective for reducing patellofemoral joint stress and enhancing patient-reported outcomes. However, the two interventions affected the athletes differently, producing distinct patterns of therapeutic superiority: resistance-band lunges resulted in greater short-term pain reduction, whereas the wall-ball squat protocol produced greater gains in knee-specific functional performance. These findings highlight the importance of individualized rehabilitation programming based on presenting impairments and desired outcomes. Ultimately, the results contribute valuable knowledge to evolving PFPS rehabilitation frameworks and support the development of phase-based, mechanism-driven therapeutic strategies for athletic populations.

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