https://doi.org/10.61919/a8129044

Original Article

Comparative Effects of Clam Shell Exercises and Short Arc Quadriceps Strengthening Exercises on Pain, Functional Disability and Quality of Life in Patellofemoral Pain Syndrome

Laraib Fatima[1], Komal Tehzeeb[2], Fahad Tanveer[3], Hafsa Zahid[4], Memoona Saleem[1]

[1] Department of Rehabilitation Sciences, Green International University, Lahore, Pakistan
[2] Assistant Professor, Department of Rehabilitation Sciences, Faculty of Medicine and Allied Health Sciences, Green International University, Lahore, Pakistan
[3] Professor and Head, Department of Rehabilitation Sciences, Green International University, Lahore, Pakistan
[4] Lecturer, Department of Rehabilitation Sciences, Green International University, Lahore, Pakistan

*Corresponding author: Komal Tehzeeb, komal.tehzeeb@giu.edu.pk

"Cite this Article" **Received**: 06 March 2026; **Accepted**: 18 March 2026; **Published**: 30 March 2026
Author Contributions: Concept: LF; Supervision: KT; Administrative Oversight: FT; Review: HZ; Drafting: LF. **Ethical Approval**: Ethical approval was Obtained from the Ethics Committee of Green International University under approval number NCT07646431 **Informed Consent**: Written informed consent was obtained from all participants; **Conflict of Interest**: The authors declare no conflict of interest. **Funding**: No external funding; **Data Availability**: Available from the corresponding author on reasonable request; **Acknowledgments**: N/A.

ABSTRACT

Background: Patellofemoral pain syndrome is a common musculoskeletal condition characterized by anterior or retropatellar knee pain, functional limitation, and reduced quality of life. Exercise therapy is central to conservative management, but direct comparative evidence between commonly prescribed hip-focused and knee-focused exercises remains limited. Objective: To compare the effects of clam shell exercises and short arc quadriceps strengthening exercises on pain, functional disability, and quality of life in patients with patellofemoral pain syndrome. Methods: An assessor-blinded randomized controlled trial was conducted among 34 adults with patellofemoral pain syndrome. Participants were allocated equally into a clam shell exercise group and a short arc quadriceps exercise group, with 17 participants in each group. Both groups received supervised exercise intervention for six weeks. Pain was assessed using the Numeric Pain Rating Scale, functional disability using the Kujala Anterior Knee Pain Scale, and quality of life using the SF-36 Health Survey. Between-group post-intervention comparisons were performed using the Mann–Whitney U test for NPRS and independent-samples t-tests for Kujala and SF-36 scores. Results: Post-intervention outcomes favored the clam shell group. Median NPRS was lower in the clam shell group than in the SAQ group (2.00 vs. 3.00; $U = 51.00$, $p = 0.001$). Kujala scores were higher in the clam shell group (89.00 ± 2.29 vs. 84.76 ± 1.64; $p < 0.001$), and SF-36 scores also favored the clam shell group (83.88 ± 2.69 vs. 77.59 ± 2.09; $p < 0.001$). Conclusion: Clam shell exercises demonstrated more favorable short-term post-intervention outcomes than short arc quadriceps strengthening exercises for pain, function, and quality of life in patients with patellofemoral pain syndrome. Further trials with baseline-adjusted analyses and longer follow-up are recommended. Keywords: Patellofemoral Pain Syndrome; Clam Shell Exercise; Short Arc Quadriceps; Pain; Kujala Score; SF-36.

INTRODUCTION

Patellofemoral pain syndrome (PFPS) is one of the most common causes of anterior knee pain and represents a substantial proportion of knee-related presentations in young and physically active adults. It is typically characterized by diffuse retropatellar or peripatellar pain that is aggravated by activities that increase patellofemoral joint loading, including stair climbing, squatting, kneeling, running, jumping, and prolonged sitting with the knee flexed. The condition is clinically important because it frequently limits mobility, reduces participation in occupational and recreational activities, and negatively affects health-related quality of life. Epidemiological evidence indicates that patellofemoral

pain is common across active and general populations, with a higher burden reported among females and individuals exposed to repeated lower-limb loading activities (1). Although PFPS is often considered a benign or self-limiting disorder, persistent symptoms may lead to reduced physical activity, recurrent pain, impaired function, and long-term disability if contributing biomechanical factors are not adequately addressed (2).

The patellofemoral joint plays an essential role in knee extension mechanics by increasing the moment arm of the quadriceps and distributing compressive forces across the anterior knee during functional movement. Efficient patellar tracking depends on coordinated interaction between static stabilizers, including the retinacula and joint geometry, and dynamic stabilizers, particularly the quadriceps, hip abductors, and hip external rotators. Alteration in any component of this kinetic chain may increase lateral patellar stress, disturb patellar alignment, and contribute to pain during loaded flexion-extension activities. PFPS has therefore been described as a multifactorial condition in which local knee impairments, proximal hip weakness, altered lower-limb kinematics, reduced neuromuscular control, training overload, and activity-related stress interact to produce symptoms (3,4).

Quadriceps dysfunction has traditionally been considered a central contributor to PFPS because inadequate quadriceps strength, particularly reduced control of the vastus medialis oblique, may compromise patellar tracking and increase anterior knee stress. Knee-focused strengthening exercises are therefore commonly prescribed to improve patellar stability, restore knee extension control, and reduce pain during functional tasks. Short arc quadriceps exercise is frequently used in early rehabilitation because it targets terminal knee extension through a limited range of motion and is considered relatively tolerable for patients with anterior knee pain. By emphasizing quadriceps activation in a controlled position, SAQ exercise may improve knee stability and functional performance while limiting excessive patellofemoral loading during early-stage rehabilitation (5,6).

More recent evidence has shifted attention toward the role of proximal hip musculature in the development and persistence of PFPS. Weakness of the hip abductors and external rotators, especially the gluteus medius and gluteus maximus, may increase femoral adduction and internal rotation during weight-bearing activities. These altered mechanics can increase dynamic knee valgus, lateral patellar tracking, and patellofemoral joint stress. On this basis, hip strengthening has become an important component of contemporary PFPS rehabilitation. Clam shell exercise is widely used to target the hip abductors and external rotators in a side-lying position and is particularly suitable for early rehabilitation because it requires minimal equipment, can be performed safely in clinical and home settings, and addresses proximal control deficits that may contribute to abnormal knee loading (7,8).

Clinical and systematic-review evidence generally supports exercise therapy as a core conservative intervention for PFPS, but uncertainty remains regarding the relative benefit of specific exercise choices. Studies comparing broad hip-focused and knee-focused rehabilitation programs have suggested that adding hip strengthening to knee-based exercise may produce greater short-term pain reduction and functional improvement in selected PFPS populations (9-12). However, many available trials evaluate combined or multi-component exercise programs rather than directly comparing commonly used individual exercises. As a result, clinicians often prescribe exercises such as clam shell and SAQ on the basis of biomechanical rationale and clinical familiarity rather than direct comparative evidence. This distinction is important because isolated exercise selection is highly relevant in routine physiotherapy practice, particularly when patients require simple, low-cost, home-based rehabilitation protocols.

The need for context-specific evidence is also important in South Asian populations, where routine cultural and occupational activities may expose individuals to repeated patellofemoral loading. Activities such as squatting, floor sitting, kneeling, stair climbing, and prolonged knee flexion are common in daily life and may influence both symptom provocation and response to rehabilitation. Although international evidence supports strengthening-based care for PFPS, locally generated comparative data remain limited. Understanding whether a proximal hip-focused exercise such as clam shell produces

superior short-term improvement compared with a distal knee-focused exercise such as SAQ may help clinicians design more targeted, feasible, and patient-specific rehabilitation programs for this population (13-16).

Despite the frequent clinical use of both exercises, direct comparative evidence between clam shell exercise and short arc quadriceps strengthening for PFPS remains limited. Existing literature supports the therapeutic value of hip and knee strengthening separately, but the relative short-term effect of these two commonly prescribed exercises on pain, functional disability, and quality of life has not been adequately clarified. This gap limits evidence-based exercise selection in routine physiotherapy settings, particularly where rehabilitation resources are limited and simple protocols are preferred. Therefore, the present randomized controlled trial was designed to compare the effects of clam shell exercises and short arc quadriceps strengthening exercises on pain, functional disability, and quality of life among adults with patellofemoral pain syndrome. The study hypothesized that there would be a significant difference between the two exercise protocols in improving pain, functional function, and health-related quality of life after the intervention period (17,18).

MATERIAL AND METHODS

This study was conducted as an assessor-blinded, two-arm randomized controlled trial to compare the effects of clam shell exercises and short arc quadriceps strengthening exercises in adults with patellofemoral pain syndrome. The study was carried out in the physical therapy department of THQ Hospital, Bhalwal, over a period of nine months after approval of the synopsis. Participants were recruited from outpatient physiotherapy services using non-probability purposive sampling, after which eligible and consenting participants were randomly allocated into two equal intervention groups. Group A received clam shell exercises, and Group B received short arc quadriceps strengthening exercises. The intervention period was six weeks, and outcome measurements were recorded at baseline and immediately after completion of the intervention.

The study population consisted of adults presenting with symptomatic patellofemoral pain syndrome. Participants were eligible if they were aged 18–40 years, male or female, clinically diagnosed with PFPS, had anterior knee pain for at least four weeks, and reported pain aggravation during activities that load the patellofemoral joint, including stair climbing, squatting, running, kneeling, or prolonged sitting. Participants were excluded if they had a history of knee surgery or fracture around the knee joint, ligamentous injury such as anterior or posterior cruciate ligament tear, meniscal injury, osteoarthritis, patellar dislocation, neurological disorders affecting lower-limb sensation or gait, systemic inflammatory disease such as rheumatoid arthritis, current participation in another physiotherapy or rehabilitation program, cognitive impairment limiting ability to follow instructions, or long-term use of steroids, strong analgesics, or anti-inflammatory medication. These criteria were applied to ensure that the sample represented patients with clinically relevant PFPS while minimizing confounding from other knee or systemic conditions.

After screening for eligibility, participants received a complete explanation of the study purpose, procedures, potential benefits, possible exercise-related discomfort, confidentiality safeguards, and voluntary nature of participation. Written informed consent was obtained before enrollment. Baseline demographic and clinical information was recorded using a structured proforma, including age, gender, height, weight, body mass index, affected side, occupation, duration of symptoms, pain-aggravating activities, previous treatment history, and relevant clinical findings. Participants were then allocated to the two intervention groups using a computerized random number generation method. Outcome assessment was performed by an assessor who was blinded to group allocation. Exercise adherence was monitored through attendance records and home exercise logs.

The sample size was calculated for comparison of two independent means using expected Kujala score values of 65.2 in the clam shell group and 72.8 in the SAQ group, with standard deviations of 8.1 and 9.3,

respectively. Using a 95% confidence level, 80% statistical power, and a pooled standard deviation of 8.73, the required sample size was 17 participants per group. Accordingly, the final analyzed sample consisted of 34 participants, with 17 participants allocated to each intervention group.

Participants in Group A performed clam shell exercises under physiotherapist supervision. The exercise was performed in a side-lying position with the hips flexed to approximately 45 degrees, knees flexed to approximately 90 degrees, and feet kept together. Participants were instructed to lift the upper knee away from the lower knee while maintaining foot contact and avoiding trunk rotation or pelvic compensation. Each session consisted of three sets of 10–15 repetitions, with a five-second hold for each repetition. The exercise was performed three to four sessions per week for six weeks. This protocol was selected to target hip abductors and external rotators, particularly the gluteal musculature, with the aim of improving proximal lower-limb control and reducing dynamic knee valgus during functional movement (19).

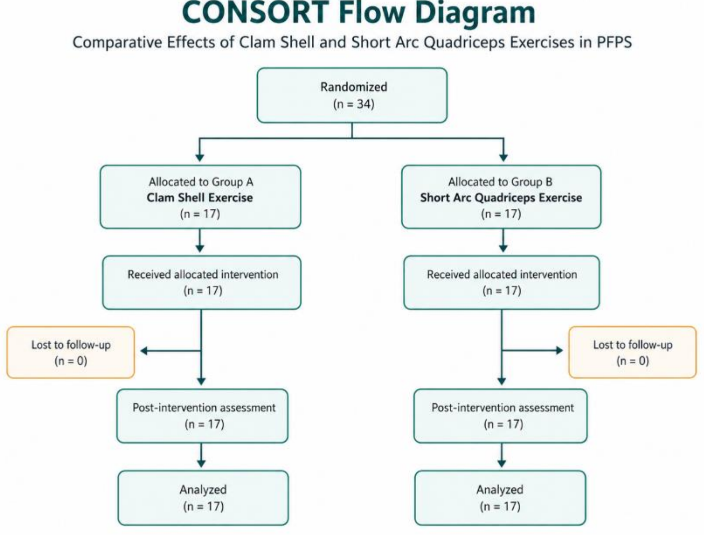

Figure 1 CONSORT Flowchart

Participants in Group B performed short arc quadriceps strengthening exercises under physiotherapist supervision. The exercise was performed in a supine lying position with a bolster or towel roll placed under the knee to maintain partial flexion. Participants were instructed to extend the knee from the supported flexed position to full available extension, hold the contraction for five seconds, and then return to the starting position in a controlled manner. Each session consisted of three sets of 10–15 repetitions, performed three to four sessions per week for six weeks. This protocol was selected to emphasize quadriceps activation through a limited arc of motion and to improve terminal knee extension control while minimizing excessive patellofemoral joint stress during early rehabilitation (20-23).

The primary outcome was pain intensity, measured using the Numeric Pain Rating Scale. NPRS is an 11-point scale ranging from 0, indicating no pain, to 10, indicating the worst imaginable pain. Functional disability was assessed using the Kujala Anterior Knee Pain Scale, which evaluates symptoms and functional limitations associated with anterior knee pain; higher scores indicate better knee-related function. Health-related quality of life was assessed using the SF-36 Health Survey, which evaluates physical functioning, role limitations, bodily pain, general health, vitality, social functioning, emotional role limitations, and mental health; higher scores indicate better perceived quality of life. All outcomes were measured at baseline and after six weeks of intervention using standardized assessment procedures (24-27).

Bias was addressed through random allocation, use of a blinded outcome assessor, standardized eligibility criteria, uniform intervention frequency, structured data collection procedures, and

monitoring of attendance and home-exercise adherence. To reduce performance variation, both exercise protocols were supervised by physiotherapy personnel and delivered using predefined positioning, movement, repetition, set, hold-time, frequency, and duration parameters. Participants were instructed not to participate in any additional physiotherapy or rehabilitation program during the study period. Data integrity was maintained through structured proforma-based recording, checking of completed forms, coding of participant information, and entry of data into statistical software for analysis.

Data were analyzed using SPSS version 26. Continuous variables were summarized as mean and standard deviation when normally distributed, and ordinal or non-normally distributed variables were summarized using median values. Categorical variables were summarized as frequencies and percentages. Normality of continuous outcome variables was assessed using the Shapiro–Wilk test. For within-group pre-post comparisons, paired-sample t-tests were used for normally distributed variables, including Kujala and SF-36 scores, while the Wilcoxon signed-rank test was used for non-normally distributed NPRS scores. For between-group post-intervention comparisons, independent-samples t-tests were used for normally distributed outcomes, and the Mann–Whitney U test was used for NPRS scores. Statistical significance was set at $p < 0.05$. Results were planned to be reported using appropriate test statistics, degrees of freedom where applicable, mean or median differences, and p-values, with interpretation aligned to the distribution and measurement level of each outcome.

The study was conducted in accordance with ethical standards for human participant research and was approved by the Green International University Ethical Review Committee. Written informed consent was obtained from all participants before enrollment. Participation was voluntary, and participants retained the right to withdraw from the study at any stage without penalty or effect on their usual care. All personal information and research data were kept confidential, participant identities were protected through anonymized records, and collected data were used only for research purposes. The interventions were non-invasive and low risk; participants were informed that temporary muscle soreness or mild exercise-related discomfort could occur, and any unexpected discomfort was addressed by the supervising physiotherapy team.

RESULTS

A total of 34 participants with patellofemoral pain syndrome were included in the final analysis. Participants were equally allocated to the clam shell exercise group and the short arc quadriceps exercise group, with 17 participants in each group. The overall sample included 18 males and 16 females. The mean age was 34.00 ± 6.55 years in the clam shell group and 28.65 ± 4.90 years in the short arc quadriceps group.

Table 1. Participant Distribution and Demographic Characteristics

Variable	Category	Value
Total sample	Overall	34
Study group	Clam shell exercise	17 (50.0)
Study group	Short arc quadriceps exercise	17 (50.0)
Gender	Male	18 (52.9)
Gender	Female	16 (47.1)
Age, years	Clam shell exercise	34.00 ± 6.55
Age, years	Short arc quadriceps exercise	28.65 ± 4.90

The study groups were numerically equal, with each group representing half of the total sample. The overall gender distribution showed a slight predominance of male participants. The clam shell group had a higher mean age than the short arc quadriceps group, with a mean difference of 5.35 years. Group-wise gender distribution and baseline group-wise clinical outcome values were not available in the supplied results, limiting formal assessment of baseline comparability.

Pre- and post-intervention descriptive scores were available for Kujala Anterior Knee Pain Scale and SF-36 when the total sample was analyzed collectively. The mean Kujala score increased from 66.50 ± 4.20

before intervention to 86.88 ± 2.91 after intervention. The mean SF-36 score increased from 50.53 ± 1.93 before intervention to 80.74 ± 3.98 after intervention.

Table 2. Overall Pre- and Post-Intervention Outcome Scores

Outcome	Baseline Mean ± SD	Post-Intervention Mean ± SD	Mean Change
Kujala Anterior Knee Pain Scale	66.50 ± 4.20	86.88 ± 2.91	20.38
SF-36 Health Survey	50.53 ± 1.93	80.74 ± 3.98	30.21

The overall descriptive analysis showed improvement in both function and health-related quality of life after the intervention period. The Kujala score increased by 20.38 points, indicating improved anterior knee function, while the SF-36 score increased by 30.21 points, indicating improved perceived quality of life. These combined pre-post values describe the overall sample response but do not distinguish the magnitude of change separately within each intervention group.

Post-intervention between-group analysis showed better outcomes in the clam shell exercise group than in the short arc quadriceps group across pain, functional disability, and quality-of-life measures. NPRS scores were compared using the Mann–Whitney U test because the pain data were non-normally distributed. Kujala and SF-36 post-intervention scores were compared using independent-samples t-tests.

Table 3. Post-Intervention Between-Group Comparison of Clinical Outcomes

Outcome	Clam Shell Exercise (n = 17)	Short Arc Quadriceps Exercise (n = 17)	Test Statistic	Mean Difference	95% CI	Effect Size	p-value
NPRS	2.00	3.00	51.00			0.65	0.001
Kujala Anterior Knee Pain Scale	89.00 ± 2.29	84.76 ± 1.64	6.20	4.24	2.85 to 5.63	2.13	<0.001
SF-36 Health Survey	83.88 ± 2.69	77.59 ± 2.09	7.61	6.29	4.61 to 7.97	2.61	<0.001

Abbreviations: NPRS, Numeric Pain Rating Scale; SF-36, Short Form-36 Health Survey; CI, confidence interval. NPRS values are presented as medians; Kujala and SF-36 values are presented as mean ± SD. Test statistic represents Mann–Whitney U for NPRS and t-values for Kujala and SF-36. Effect size represents rank-biserial correlation for NPRS and Cohen's d for Kujala and SF-36.

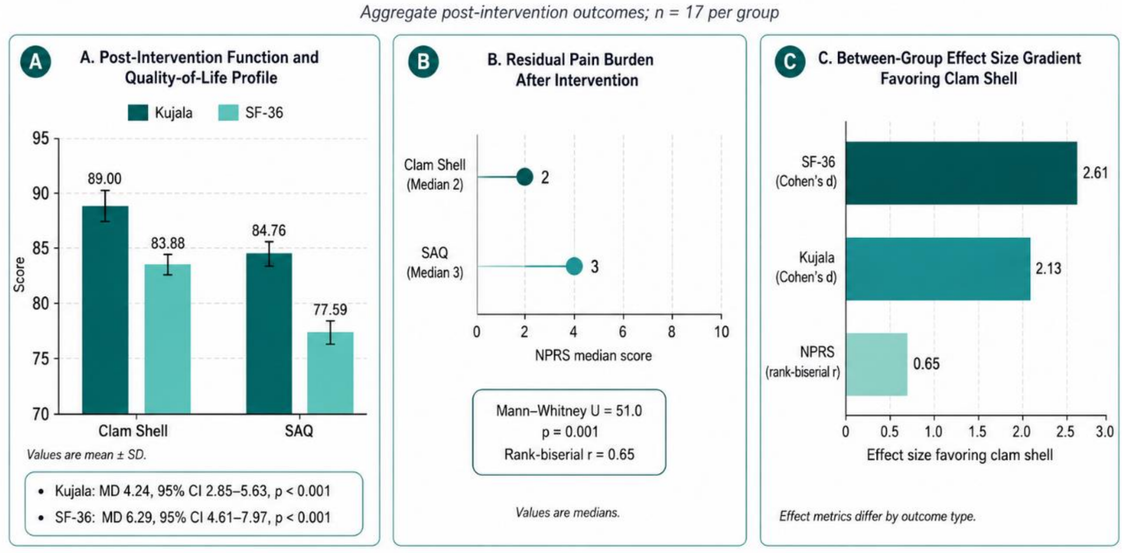

Figure 1. Comparative Post-Intervention Outcome Gradient in Patellofemoral Pain Syndrome

The panelled figure demonstrates a consistent post-intervention outcome gradient favoring clam shell exercises over short arc quadriceps strengthening exercises across pain, function, and health-related quality of life. The clam shell group showed a lower residual NPRS median score than the SAQ group, with median scores of 2.00 and 3.00, respectively, and the between-group pain difference was statistically

significant on Mann–Whitney U testing (U = 51.00, p = 0.001; rank-biserial r = 0.65). Functional recovery also favored the clam shell group, with a higher post-intervention Kujala score than the SAQ group (89.00 ± 2.29 vs. 84.76 ± 1.64), corresponding to a mean difference of 4.24 points, 95% CI 2.85 to 5.63, and Cohen's d = 2.13. A similar pattern was observed for quality of life, where the clam shell group achieved a higher SF-36 score than the SAQ group (83.88 ± 2.69 vs. 77.59 ± 2.09), with a mean difference of 6.29 points, 95% CI 4.61 to 7.97, and Cohen's d = 2.61. Collectively, the visual pattern supports a clinically meaningful post-intervention advantage for the hip-focused clam shell protocol, although interpretation should remain limited to post-treatment aggregate comparisons because group-wise baseline outcome values and change scores were not available.

The clam shell exercise group had a lower post-intervention median NPRS score than the short arc quadriceps group, with median pain scores of 2.00 and 3.00, respectively. The Mann–Whitney U test showed a statistically significant between-group difference in post-intervention pain scores, with an effect size of 0.65. Functional outcomes also favored the clam shell group, with a post-intervention Kujala score of 89.00 ± 2.29 compared with 84.76 ± 1.64 in the short arc quadriceps group. The mean between-group difference was 4.24 points, with a 95% confidence interval from 2.85 to 5.63 and a Cohen's d of 2.13. Quality-of-life outcomes showed a similar pattern, with the clam shell group achieving a higher SF-36 score than the short arc quadriceps group. The mean between-group difference in SF-36 score was 6.29 points, with a 95% confidence interval from 4.61 to 7.97 and a Cohen's d of 2.61.

The post-intervention findings indicate that both interventions were associated with improvement, but the available between-group results favored clam shell exercises for pain reduction, anterior knee function, and health-related quality of life. However, because group-wise baseline outcome scores and group-wise change scores were not available in the supplied results, the between-group interpretation is based on post-intervention comparisons rather than baseline-adjusted or change-score analysis.

DISCUSSION

The present randomized controlled trial compared the short-term effects of clam shell exercises and short arc quadriceps strengthening exercises on pain, functional disability, and health-related quality of life among adults with patellofemoral pain syndrome. The post-intervention findings favored the clam shell exercise group across all measured clinical outcomes. Participants who received clam shell exercises demonstrated a lower median NPRS pain score than those who received SAQ exercises, while also achieving higher Kujala Anterior Knee Pain Scale and SF-36 scores after the intervention period. These findings suggest that a hip-focused exercise targeting proximal lower-limb control may provide greater short-term clinical benefit than an isolated knee-focused quadriceps exercise in this sample. However, because group-wise baseline outcome values and change-score analyses were not available in the supplied results, the interpretation should remain limited to post-intervention between-group differences rather than definitive baseline-adjusted superiority.

The greater reduction in residual pain observed in the clam shell group is biomechanically plausible in the context of PFPS rehabilitation. Patellofemoral pain is frequently associated with altered lower-limb mechanics, including excessive femoral adduction and internal rotation, dynamic knee valgus, and increased lateral patellofemoral joint stress during functional activities. Weakness or delayed control of the hip abductors and external rotators may contribute to these movement patterns, particularly during stair negotiation, squatting, kneeling, and prolonged weight-bearing activities. By emphasizing activation of the gluteal musculature, clam shell exercises may improve proximal control of femoral motion and reduce abnormal stress transmission to the patellofemoral joint. This mechanism is consistent with previous evidence supporting the role of hip strengthening in improving pain and function among patients with PFPS (9-12).

The present findings are also aligned with clinical studies reporting beneficial effects of clamshell or hip-focused strengthening exercises in PFPS populations. Ijaz et al. reported improvement in pain and

functional outcomes after clamshell exercises among patients with PFPS, supporting the clinical relevance of targeting the hip abductors and external rotators in rehabilitation (18). Similarly, Tahir et al. found that adding hip abductor and external rotator strengthening to knee-focused rehabilitation produced greater short-term pain reduction than knee strengthening alone among sedentary women with PFPS (21). The current study extends this rationale by directly comparing a commonly used hip-focused exercise with a commonly used knee-focused exercise and showing that the post-intervention outcome profile favored the clam shell protocol. Although direct comparison across studies is limited by differences in population, intervention structure, outcome timing, and analysis, the overall pattern supports the inclusion of proximal hip strengthening in PFPS management.

The SAQ group also demonstrated clinically favorable post-intervention outcomes, which is consistent with the established role of quadriceps strengthening in PFPS rehabilitation. The quadriceps, particularly the vastus medialis oblique, contributes to patellar alignment and terminal knee extension control. Short arc quadriceps exercises are commonly prescribed because they allow focused quadriceps activation within a limited range of motion and may be tolerated by patients with anterior knee pain. Previous studies have shown that SAQ exercises can reduce pain, improve quadriceps muscle activity, and enhance health-related quality of life in patients with anterior knee pain or PFPS (20,22). In the present study, the SAQ group achieved post-intervention improvements, but the magnitude of post-treatment pain, function, and quality-of-life outcomes was less favorable than that observed in the clam shell group. This may indicate that knee-focused strengthening alone does not fully address the proximal biomechanical contributors that are often involved in PFPS.

The functional outcome results further support the potential relevance of hip-focused rehabilitation. The clam shell group achieved a higher post-intervention Kujala score than the SAQ group, with a mean between-group difference of 4.24 points. The Kujala scale reflects symptoms and functional capacity during activities such as walking, stair climbing, squatting, running, jumping, and prolonged sitting, which are commonly impaired in PFPS. Improvement in this scale may therefore reflect better tolerance of patellofemoral loading during daily activities. The observed advantage in the clam shell group may be explained by improved control of hip adduction and internal rotation, which could reduce lateral patellar stress during functional movement. Nevertheless, the absence of direct biomechanical or electromyographic assessment prevents confirmation of this mechanism, and the explanation should be considered clinically plausible rather than directly proven by the present trial.

Quality-of-life outcomes also favored the clam shell group. The higher SF-36 score after intervention suggests that improvements were not limited to pain intensity or knee-specific function but may have extended to broader perceived physical and psychosocial health. This is clinically important because PFPS can limit household activities, occupational performance, sports participation, mobility, and confidence in movement. Persistent anterior knee pain may also contribute to reduced physical activity and deconditioning. A rehabilitation strategy that improves both pain and function may therefore have meaningful implications for overall quality of life. However, the SF-36 is a broad health-related quality-of-life tool, and future studies may benefit from including both generic and knee-specific quality-of-life measures to better define the domains most responsive to exercise intervention.

The findings have practical relevance for physiotherapy settings where simple, low-cost, and home-based exercise protocols are needed. Clam shell exercises require minimal equipment, are easy to teach, and can be incorporated into early-stage rehabilitation programs. In populations where daily activities commonly involve squatting, kneeling, stair use, and floor sitting, proximal hip control may be especially important for reducing patellofemoral stress during repeated functional loading. The present results suggest that clinicians should consider including clam shell exercises as a key component of PFPS rehabilitation, particularly when patients demonstrate signs of hip abductor or external rotator weakness, dynamic knee valgus, or poor lower-limb control. At the same time, the findings should not

be interpreted as evidence that SAQ exercises are unnecessary; rather, they support a more integrated rehabilitation approach that addresses both proximal hip control and distal quadriceps function.

Several limitations should be considered when interpreting the results. First, the sample size was small, with 17 participants in each group, which limits precision and generalizability. Second, the study was conducted at a single center, and the findings may not fully represent patients from other clinical, occupational, athletic, or community settings. Third, although the study used assessor blinding, participant blinding was not practically feasible because the two exercise protocols were visibly different. Fourth, group-wise baseline values for NPRS, Kujala, and SF-36 were not available in the supplied results, preventing a full assessment of baseline equivalence and limiting the ability to interpret between-group differences as true treatment effects independent of baseline status. Fifth, the analysis relied mainly on post-intervention comparisons rather than baseline-adjusted models or group-wise change-score comparisons. Sixth, adherence to home exercise could not be completely controlled, and differences in exercise performance outside supervised sessions may have influenced outcomes. Finally, the study assessed only short-term outcomes after six weeks and did not determine whether the observed benefits were sustained over time.

Future trials should include larger samples, multicenter recruitment, concealed allocation, clearly reported baseline group comparability, group-wise change scores, confidence intervals, effect sizes, and intention-to-treat analysis where appropriate. Longer follow-up periods are needed to determine durability of treatment effects. Additional biomechanical or electromyographic outcomes may also help clarify whether improvements after clam shell exercise are mediated by changes in gluteal activation, femoral control, dynamic valgus, or patellar tracking. Studies comparing combined hip-and-knee protocols with isolated exercise approaches would be particularly useful, as contemporary PFPS rehabilitation is likely to be most effective when both proximal and distal impairments are addressed. Despite these limitations, the present study contributes clinically relevant comparative evidence and supports the role of hip-focused strengthening as an important component of short-term PFPS rehabilitation.

CONCLUSION

This randomized controlled trial found that clam shell exercises produced more favorable post-intervention outcomes than short arc quadriceps strengthening exercises in adults with patellofemoral pain syndrome. After six weeks of intervention, the clam shell group demonstrated lower residual pain, better anterior knee function, and higher health-related quality-of-life scores than the SAQ group. These findings suggest that targeting proximal hip musculature may offer meaningful short-term benefit in PFPS rehabilitation, particularly for improving pain and functional performance during activities that load the patellofemoral joint. However, because the available analysis was based on post-intervention comparisons and did not include group-wise baseline-adjusted or change-score results, the findings should be interpreted cautiously. Larger, methodologically rigorous trials with longer follow-up and detailed biomechanical assessment are recommended to confirm the clinical durability and mechanisms of these effects.

REFERENCES

1. Smith BE, Selfe J, Thacker D, Hendrick P, Bateman M, Moffatt F, et al. Incidence and prevalence of patellofemoral pain: a systematic review and meta-analysis. PLoS One. 2018;13(1):e0190892.

2. Motealleh A, Mohamadi M, Moghadam MB, Nejati N, Arjang N, Ebrahimi N. Effects of core neuromuscular training on pain, balance, and functional performance in women with patellofemoral pain syndrome: a clinical trial. J Chiropr Med. 2019;18(1):9-18.

3. Vora M, Curry E, Chipman A, Matzkin E, Li X. Patellofemoral pain syndrome in female athletes: a review of diagnoses, etiology and treatment options. Orthop Rev. 2018;9(4):7281.

4. Tramontano M, Pagnotta S, Lunghi C, Manzo C, Manzo F, Consolo S, et al. Assessment and management of somatic dysfunctions in patients with patellofemoral pain syndrome. J Osteopath Med. 2020;120(3):165-73.

5. Emamvirdi M, Letafatkar A, Khaleghi Tazji M. The effect of valgus control instruction exercises on pain, strength, and functionality in active females with patellofemoral pain syndrome. Sports Health. 2019;11(3):223-37.

6. Petersen W, Ellermann A, Gösele-Koppenburg A, Best R, Rembitzki IV, Brüggemann GP, et al. Patellofemoral pain syndrome. Knee Surg Sports Traumatol Arthrosc. 2014;22(10):2264-74.

7. Dixit S, DiFiori JP, Burton M, Mines B. Management of patellofemoral pain syndrome. Am Fam Physician. 2007;75(2):194-202.

8. Saltychev M, Dutton RA, Laimi K, Beaupre GS, Virolainen P, Fredericson M. Effectiveness of conservative treatment for patellofemoral pain syndrome: a systematic review and meta-analysis. J Rehabil Med. 2018;50(5):393-401.

9. Xie P, István B, Liang M. The relationship between patellofemoral pain syndrome and hip biomechanics: a systematic review with meta-analysis. Healthcare. 2022;10(8):1491.

10. Pereira PM, Baptista JS, Conceição F, Duarte J, Ferraz J, Costa JT. Patellofemoral pain syndrome risk associated with squats: a systematic review. Int J Environ Res Public Health. 2022;19(15):9241.

11. Gaitonde DY, Ericksen A, Robbins RC. Patellofemoral pain syndrome. Am Fam Physician. 2019;99(2):88-94.

12. Kasitinon D, Li WX, Wang EXS, Fredericson M. Physical examination and patellofemoral pain syndrome: an updated review. Curr Rev Musculoskelet Med. 2021;14(6):406-12.

13. Gulati A, McElrath C, Wadhwa V, Shah JP, Chhabra A. Current clinical, radiological and treatment perspectives of patellofemoral pain syndrome. Br J Radiol. 2018;91(1086):20170456.

14. Pollatos D, Chandolias K, Giordamni MA, Chalkia A, Trevlaki E, Pollatos D. Review of new data in physiotherapeutic approach to patellofemoral pain syndrome. J Biosci Med. 2021;9(2):103-16.

15. Luo Y, Chen X, Shen X, Chen L, Gong H. Effectiveness of Kinesio tape in the treatment of patients with patellofemoral pain syndrome: a systematic review and meta-analysis. Medicine. 2024;103(23):e38438.

16. Niemuth E, Monson J. Surgical rehabilitation for select patellar stabilizing procedures. In: Patellofemoral Pain, Instability, and Arthritis: Clinical Presentation, Imaging, and Treatment. Cham: Springer; 2020. p. 359-78.

17. Wallis JA, Roddy L, Bottrell J, Parslow S, Taylor NF. A systematic review of clinical practice guidelines for physical therapist management of patellofemoral pain. Phys Ther. 2021;101(3):pzab021.

18. Ijaz M, Tabassum MN, Ahmad M, Zubair A, Arshad S, Zahid E. Role of clamshell exercises on pain and functional outcomes in patients with patellofemoral pain syndrome. Healer J Physiother Rehabil Sci. 2025;5(2):244-9.

19. Kim D. Effect of modified clamshell exercise on gluteus medius, quadratus lumborum and anterior hip flexor in participants with gluteus medius weakness. J Korean Soc Phys Med. 2019.

20. Hasan S, Lasi F, Saleem S, Fazal A, Khan R. Isometric and short arc exercises effect on the quadriceps muscle of patellofemoral knee pain patients. Int J Endorsing Health Sci Res. 2022;10(2):220-6.

21. Tahir I, Zoonish R, Zehra S, Shah SMA, Riaz M, Amanat R, et al. Comparing the effects of strengthening exercises of knee and hip muscles in reducing pain in patients with patellofemoral pain syndrome: a randomized clinical trial. J Health Wellness Community Res. 2025:e496.

22. Abbasi MS, Kazmi SAM, Baig N. Effectiveness of short arc and isometric quadriceps exercises on pain, muscle activity and health related quality of life in patients with anterior knee pain. Pak J Rehabil. 2020;9(1):41-6.

23. Kumar M, Srivastava S. Electromyographic analysis of VMO and VL across straight leg raise, short arc quad, medial tibial rotation and hip adduction in normal individuals. Work. 2020;65(1):153-9.

24. Sutlive TG, Golden A, King K, Morris WB, Morrison JE, Moore JH, et al. Short-term effects of trigger point dry needling on pain and disability in subjects with patellofemoral pain syndrome. Int J Sports Phys Ther. 2018;13(3):462-73.

25. Duong V, Oo WM, Ding C, Culvenor AG, Hunter DJ. Evaluation and treatment of knee pain: a review. JAMA. 2023;330(16):1568-80.

26. Berghmans DD, Lenssen AF, Emans PJ, de Bie RA. Functions, disabilities and perceived health in the first year after total knee arthroplasty: a prospective cohort study. BMC Musculoskelet Disord. 2018;19(1):250.

27. Cai T, Verze P, Bjerklund Johansen TE. The quality of life definition: where are we going? Uro. 2021;1(1):14-22.

28. Grimaldi A. The clam exercise appeared least favourable in terms of recruiting GMed muscle activity.

29. Cheon S, Lee JH, Jun HP, An YW, Chang E. Acute effects of open kinetic chain exercise versus those of closed kinetic chain exercise on quadriceps muscle thickness in healthy adults. Int J Environ Res Public Health. 2020;17(13):4669.