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EFFECTS OF OPEN CHAIN, CLOSED CHAIN AND COMBINED EXERCISES ON PAIN INTENSITY AND QUADRICEPS MUSCLE STRENGTH IN PATIENTS WITH ANTERIOR KNEE PAIN: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Background: Anterior knee pain (AKP) is a very prevalent musculoskeletal problem causing significant functional impairment in individuals who are physically active. Although exercise therapy is a well established as primary treatment, comparative effectiveness of open kinetic chain (OKC) exercises, closed kinetic chain (CKC) exercises and combined OKC+CKC exercise protocols remains under studied. No randomized controlled trial has simultaneously compared these three approaches in patients with acute AKP.

Objective: To compare effects of OKC, CKC and combined OKC+CKC exercise protocols on pain intensity and quadriceps muscle strength after four weeks of intervention.

Methods: A three-arm, parallel group randomized controlled trial enrolled 96 participants (aged 18-40 years) with acute AKP. Participants were randomized to Group A (OKC exercises, n = 32), Group B (CKC exercises, n = 32) and Group C (combined OKC+CKC, n = 32). All groups received standardized conventional physical therapy for anterior knee pain. Interventional exercises were performed three days per week at a dosage of four sets of 12 repetitions for four weeks. General Linear Model (GLM) repeated measures ANOVA with Bonferroni post hoc corrections and intention to treat (ITT) analysis were applied.

Results: Significant Time × Group interactions were observed for NPRS ($F(2, 93) = 37.880$, $p < .001$) and quadriceps strength ($F(2, 93) = 2674.875$, $p < .001$). Group C demonstrated greatest pain reduction (mean NPRS decrease: 4.59 points; 71.0% from baseline) and quadriceps strength gains (mean increase: +9.22 kg; 63.9%). Post hoc analysis confirmed Group C was significantly superior to both Groups A and B ($p < 0.001$). No significant difference was found between Groups A and B for either outcome.

Conclusion: Combined OKC and CKC exercises generated superior improvements in pain intensity and quadriceps muscle strength compared to single modality intervention of OKC or CKC in acute AKP.

KEYWORDS: anterior knee pain, patellofemoral pain, open kinetic chain exercise, closed kinetic chain exercise, quadriceps strength, randomized controlled trial, rehabilitation

INTRODUCTION

Anterior knee pain (AKP), usually described synonymous with patellofemoral pain (PFP), is one of the most common and clinically challenging musculoskeletal conditions encountered in physiotherapy and rehabilitation practice. It is defined as an insidious onset pain localized to anterior, retro-patellar or peripatellar region. It is consistently provoked by activities that load the patellofemoral joint e.g. squatting, stair climbing, running, jumping and prolonged sitting (Vikhe et al., 2024). Apart from being a benign or self-limiting complaint, AKP frequently persists for years, impairs quality of life of sufferer, limits participation in physical activity and predisposes affected people to long-term patella-femoral osteoarthritis (Barton et al., 2022). Annual prevalence of the condition in general population has been estimated at 22.7%, rising to 28.9% in adolescents and exceeding 570 per 1,000 person-years in military populations (Smith et al., 2018). This underscores its burden on individuals as well as its healthcare significance.

The patho-mechanics of AKP are multifactorial and mostly interconnected. At local levels, quadriceps weakness and atrophy, particularly of vastus medialis oblique (VMO), decline efficiency of patellar stabilization, allowing lateral malalignment and elevated patellofemoral posterior contact pressure (Kochar et al., 2024; Adeel et al., 2024). Proximally, deficits in hip abductor and external rotator strength allow excessive femoral internal rotation and adduction during weight bearing activities, increasing dynamic valgus and precipitating stress on lateral patellofemoral facet (Bloomer & Durall, 2015; Xie et al., 2023). These biomechanical impairments are accompanied by neurophysiological alterations; including disrupted proprioception, impaired motor unit recruitment and central sensitization; that further amplify pain experience and perpetuate cycle of disuse and weakness (Bartsch et al., 2024). Taken together, evidence points unequivocally towards a need for rehabilitation strategies that should address both local quadriceps mechanism and broader proximal kinetic chain.

Exercise therapy is a most consistently effective intervention for AKP, supported by multiple systematic reviews and clinical practice guidelines (Vikhe et al., 2024; Halabi et al., 2025). Within this body of available evidence, two common exercise categories have been extensively studied; open kinetic chain (OKC) exercises and closed kinetic chain (CKC) exercises. OKC exercises, such as straight leg raises, seated knee extensions and side lying hip abduction, involve free distal limb movement keeping proximal segment stabilized. Their principal advantage is direct, isolated loading of quadriceps muscles through their full range of motion. This generates targeted neuromuscular stimulus and is particularly effective for addressing VMO weakness central to patellar mal-tracking (Adeel et al., 2024). CKC exercises e.g. wall slides, terminal knee extensions in standing and step-ups, involve the foot to remain fixed on floor or weight-bearing. Thereby, they engage quadriceps, hamstrings, gluteals and hip stabilizers in coordinated and functional co-contraction patterns (Kochar et al., 2024; Kamel et al., 2024). This multi-joint engagement more closely replicates neuromuscular demands of daily living activities and sport and is considered to facilitate broader kinetic chain rehabilitation.

Despite the widespread use of both these modalities, comparative literature highlights an important unresolved question. Several trials report that CKC exercises are superior for functional outcomes, attributing this to their engagement of hip stabilizers and weight bearing neuromuscular control (Xie et al., 2023). Others inform OKC exercises to produce greater quadriceps torque improvements, particularly in early rehabilitation phase (Adeel et al., 2024). Systematic reviews and meta-analyses of combined knee and hip region exercise programs, inherently incorporating both OKC and CKC elements, consistently report better outcomes compared to knee only protocols. This suggests that combination of direct quadriceps loading with proximal kinetic chain activation produces effects which neither strategy achieves when applied in isolation (Halabi et al., 2025; Fan et al., 2023). This emerging evidence directs towards a synergistic model of exercise prescription for AKP, yet no randomized trial has directly tested this consideration with a three arm design comparing all three intervention protocols head to head.

This evidence gap has real clinical implications and consequences. Without direct comparative data, physiotherapists usually rely on theoretical frameworks and indirect evidence when making exercise prescription decisions for patients with acute AKP; a population in which early, targeted rehabilitation has greatest potential to help prevent chronicity (Barton et al., 2022). The present study was designed to address this gap through a three arm, parallel group RCT comparing OKC, CKC and combined OKC+CKC exercises in patients with acute AKP over four weeks. We hypothesized that combined protocol would produce significantly greater improvements in pain intensity and quadriceps muscles' strength than either modality used alone; by simultaneously leveraging both; targeted quadriceps strengthening of OKC exercises and functional neuromuscular integration of CKC exercises.

METHODS

Study Design

This study was a three arm, parallel group RCT conducted at Outpatient Department of Rehabilitation Sciences, Ziauddin Hospital (Kemari, North Karachi and Clifton campuses), Karachi, Pakistan. The study was designed, conducted and reported in accordance with CONSORT guidelines. Ethical approval was obtained from Ethical Review Committee of Ziauddin University with reference code: 10700725DAPT dated 23rd September 2025. The study ensured to abide by guidelines of the Declaration of Helsinki and all participants provided a written informed consent before enrolment.

Participants

Male and female patients aged 18-40 years were eligible participants if they had a clinical diagnosis of acute AKP, defined as anteriorly located knee pain of less than or equal to three months duration, provoked by at least one loading activity (e.g. squatting, stair climbing, prolonged sitting or running). Diagnosis was confirmed by a consultant physiatrist prior to physiotherapy referral. Restriction to acute presentations (≤3 months) was deliberate, because this early intervention is most likely to prevent transition of AKP to chronicity, which carries a substantially poorer prognosis (Barton et al., 2022). Participants were excluded form selection if they had a history of knee surgery in preceding 12 months, diagnosed radiculopathy, knee infection, any malignancy or inflammatory joint disease, frequent patellar subluxation, dislocation or instability, prior physical therapy for current episode or any systemic condition precluding safe exercise participation.

Sample Size

Sample size was calculated using Open Epi software, based on effect sizes from a comparable RCT examining OKC and CKC exercises in knee pain patients (Ng et al., 2022). Cohen's d was derived from pooled standard deviation adjusted mean difference. A minimum of 29 participants per group was required for 80% power at $\alpha = 0.05$. With a 10% attrition allowance applied, final target sample was 32 participants per group (total N = 96).

Randomization, Allocation Concealment and Blinding

Participants were randomly assigned using sequentially numbered opaque sealed envelopes (SNOSE) prepared by a researcher independent of recruitment and data collection. Allocation was concealed until baseline assessment was completed. Outcome assessors and study statistician were blinded to group allocation throughout the trial. Participants were blinded to the comparative study arms. Treating physiotherapists were not blinded, as the nature of exercise delivery makes this impossible.

Interventions

All groups completed a four-week protocol, three sessions per week on alternate days, with sessions lasting 20-30 minutes. All exercises were performed at 4 sets of 12 repetitions. Standardized conventional therapy was provided to all groups before each session: hot pack (10 minutes, 37-40°C) and TENS (10 minutes, 7 Hz, pulse rate >100 pps). Each session included a 5-minute warm-up (calf, hamstring and quadriceps stretches) and 5-minute cool-down (slow walking). Specific exercise protocols were as follows:

Group A (OKC): It comprised of intervention protocol as (1) Straight leg raise; in supine lying, leg lifted 20 cm with knee in full extension. (2) Seated knee extension; upright sitting, knee extended and held briefly (5-10seconds), then slowly lowered to 90^0 knee flexion. (3) Hip abduction; side-lying, upper leg lifted to maximal available limit with neutral hip alignment. (4) Hip adduction; side-lying, bottom leg lifted with adductor contraction while upper leg was fully flexed at hip.

Group B (CKC): It comprised of interventions as (1) Standing to terminal knee extension from 90^0 flexion with resistance band. (2) Wall slide; back against wall, bend knees at 30-40° flexion, hold 5 seconds and return. (3) Forward step-up; affected leg steps onto a platform with full weight transfer by bringing unaffected leg to same platform, then controlled step-down. (4) Lateral step-up; same procedure as step 3 performed laterally.

Group C (OKC+CKC): All four OKC exercises from Group A and all four CKC exercises from Group B, performed concurrently within each session at the same dosage (4 sets of 12 repetitions per exercise).

Outcome Measures

Outcomes were assessed at baseline and four weeks post-intervention by a blinded assessor. Total two outcomes were assessed as follows:

Pain intensity was measured using the Numeric Pain Rating Scale (NPRS; 0–10, where 0 = no pain and 10 = worst imaginable pain). Test-retest reliability is excellent (ICC = 0.84; Kochar et al., 2024). The established minimum clinically important difference (MCID) for NPRS in musculoskeletal conditions is 1.74-2.0 points; a reduction of ≥30% from baseline is considered to reflect 'much better' improvement (Salaffi et al., 2004; Olsen et al., 2018).

Quadriceps muscle strength was assessed using a hand held dynamometer (reliability r = 0.97-0.98), with participants seated at 90° knee flexion. Three trials were performed and mean recorded in kilograms (kg).

Missing Data

Two participants withdrew one week before study completion, one from Group A and one from Group C. Missing post intervention values were estimated using multiple imputation, consistent with intention to treat (ITT) principles, ensuring all 96 enrolled participants were included in final analysis.

Statistical Analysis

Data normality was assessed using Kolmogorov-Smirnov and Shapiro-Wilk tests. Gender distribution across groups was assessed using Pearson chi-square test. Homogeneity of variance was verified by Levene's test. A General Linear Model (GLM) with repeated measures analysis of variance (ANOVA) was applied, with Time as within-subjects factor (two levels: pre and post) and Group as the between-subjects factor (three levels). Time × Group interaction was the primary inferential test. Bonferroni post hoc corrections were applied for between-group comparisons. Statistical significance was set at $p < .05$. All analyses were performed using IBM SPSS version 26.0.

RESULTS

Participant Flow and Baseline Characteristics

A total of 184 individuals were screened; 88 were excluded and 96 were enrolled and randomized (n = 32 per group). Two participants withdrew one week before completion, one from Group A and one from Group C and their data were estimated using multiple imputation method. All 96 participants were analyzed on an ITT basis. The CONSORT flow diagram is presented in Figure-1.

Baseline demographic and clinical characteristics are presented in Table-1. The three groups were comparable for age, gender distribution and all baseline outcome measures, with no statistically significant between-group differences.

Table-1: Baseline Demographic and Clinical Characteristics (N = 96)

Variable	Group A OKC (n=32)	Group B CKC (n=32)	Group C Combined (n=32)	p value

Age (years): Mean (SD)	27.06 (2.96)	27.13 (2.94)	26.72 (2.91)	0.091
Gender (M/F)	17/15	16/16	16/16	0.083 (χ^2)
NPRS: Mean (SD)	6.41 (1.04)	6.66 (0.94)	6.47 (0.98)	0.751
Quadriceps Strength, kg: Mean (SD)	15.12 (1.23)	13.78 (1.13)	14.43 (1.22)	0.0657

Note. M = Male; F = Female; SD = Standard Deviation.

Enrollment

Assessed for eligibility (n = 184)

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Excluded (n = 88)
- Not meeting inclusion criteria (n = 68)
- Declined to participate (n = 9)
- Other reasons (n = 11)

Randomized (n = 96)

Allocation

↓

Group A	Group B	Group C
Allocated (n = 32) Received allocated intervention (n = 32)	Allocated (n = 32) Received allocated intervention (n = 32)	Allocated (n = 32) Received allocated intervention (n = 32)

Follow-Up

↓

Completed intervention (n = 31)	Completed intervention (n = 32)	Completed intervention (n = 31)
Withdrew ~1 week before completion (n = 1) Lost to follow-up (n = 1)	Withdrew (n = 0) Lost to follow-up (n = 0)	Withdrew ~1 week before completion (n = 1) Lost to follow-up (n = 1)

Analysis

↓

Analyzed (n = 32)	Analyzed (n = 32)	Analyzed (n = 32)
Excluded from analysis (n = 0) Missing outcome data imputed (n = 1)	Excluded from analysis (n = 0) Missing outcome data imputed (n = 0)	Excluded from analysis (n = 0) Missing outcome data imputed (n = 1)

Figure-1: CONSORT flow diagram of participants through the trial

Primary Outcomes

All three groups demonstrated significant improvements in both pain intensity and quadriceps muscle strength from baseline to post-intervention. The combined OKC+CKC group consistently produced the greatest magnitude of change on both outcomes. Descriptive statistics, GLM results and post hoc comparisons are presented in Tables-2, 3 and 4, respectively. Results graphs are presented in Figure-2 and 3.

Table-2: Pre and Post-Intervention Means, Changes and GLM Repeated Measures ANOVA Results

	Group	Pre M (SD)	Post M (SD)	Mean Change	% Change	F (Time)	F (Time×Grp)	p
NPRS	Group A (OKC)	6.41 (1.04)	4.03 (1.09)	−2.38	−37.1%	889.027	37.880	<0.001
	Group B (CKC)	6.66 (0.94)	3.81 (0.93)	−2.85	−42.8%			
	Group C (Combined)	6.47 (0.98)	1.88 (0.91)	−4.59	−71.0%			

	Group	Pre M (SD)	Post M (SD)	Mean Change	% Change	F (Time)	F (Time×Grp)	p
Quad. Strength (kg)	Group A (OKC)	15.12 (1.23)	19.29 (1.10)	+4.17	+27.6%	46153.301	2674.875	<0.001
	Group B (CKC)	13.78 (1.13)	19.24 (1.02)	+5.47	+39.7%			
	Group C (Combined)	14.43 (1.22)	23.64 (1.37)	+9.22	+63.9%			

Note. GLM = General Linear Model; M=Mean; NPRS = Numeric Pain Rating Scale; SD = Standard Deviation.

Table-3: Levene's Test for Homogeneity of Variance

Outcome	F (Pre)	p (Pre)	F (Post)	p (Post)
NPRS	0.399	.672	0.716	.491
Quadriceps Muscle Strength	0.166	.847	1.621	.203

Table-4: Bonferroni Post Hoc Comparisons; Between-Group Differences

Outcome	Comparison	Mean Diff.	SE	P vlaue	Significant
NPRS	Group A vs. Group B	−0.016	0.206	1.000	No
	Group A vs. Group C	1.047	0.206	<0.001	Yes
	Group B vs. Group C	1.063	0.206	<0.001	Yes
Quadriceps Strength	Group A vs. Group B	0.694	0.294	0.061	No
	Group A vs. Group C	−1.830	0.294	<0.001	Yes
	Group B vs. Group C	−2.523	0.294	<0.001	Yes

Note. SE = Standard Error; NPRS: Numeric Pain Rating Scale

Pain Intensity (NPRS)

All three groups achieved statistically significant reductions in pain over four-week intervention period. This confirmed that both OKC and CKC exercise protocols are clinically effective for acute AKP when applied with adequate dosage and conventional therapy (Table-2). Time × Group interaction was also statistically significant, indicating that trajectory of pain reduction differed meaningfully across all groups (Table-2). Specifically, Combined OKC+CKC group generated a largest absolute pain reduction, surpassing both individual (OKC or CKC) exercise protocol groups by a clinically and statistically significant margin (Table-4).

understanding these results against previously established clinical benchmarks adds important context. The MCID for NPRS in musculoskeletal conditions is 1.74-2.0 points change and a ≥30% reduction from baseline score reflects patients' perceived **"much better"** status (Salaffi et al., 2004; Olsen et al., 2018). All three groups exceeded MCID threshold, confirming genuine and meaningful pain relief across all intervention protocols. However, only Group C exceeded more demanding 'much better' threshold of 30% reduction in pain, achieving a 71.0% reduction compared to 37.1% and 42.8% in Groups A and B, respectively. This difference in intensity of pain relief has tangible clinical relevance; patients in Group C reached near complete pain resolution by post intervention. Whereas those in Groups A and B, while meaningfully improved, retained moderate residual pain.

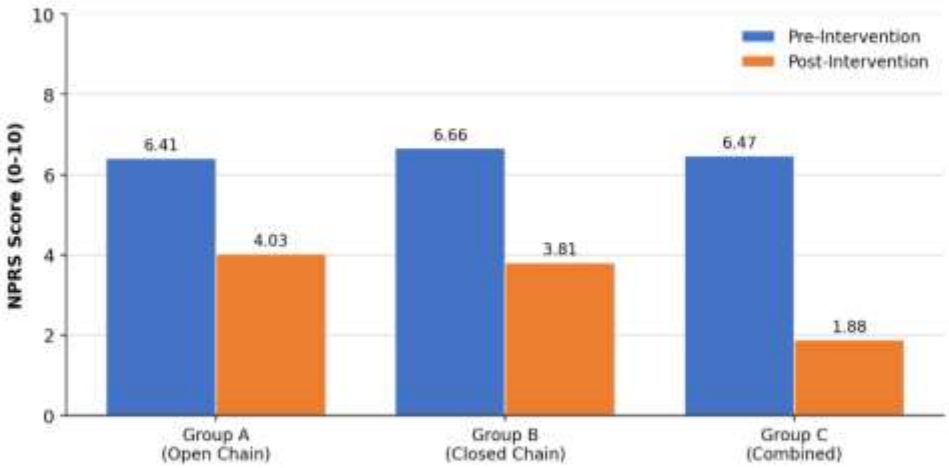

Figure-2. Mean NPRS scores pre and post-intervention by group.

Quadriceps Muscle Strength

All three groups demonstrated appreciable gains in quadriceps muscle strength over four week intervention period, with all Time x Group interaction effects reaching statistical significance (Table-2). Group C produced a greatest absolute as well as relative strength gains, exceeding both individual protocol groups (A and B) by statistically significant margins (Table-4). Difference between Groups A and B did not reach statistical significance ($p = .061$). This shows that OKC and CKC exercises in isolation produced mutually comparable strength outcomes when delivered at same dosage with conventional therapy.

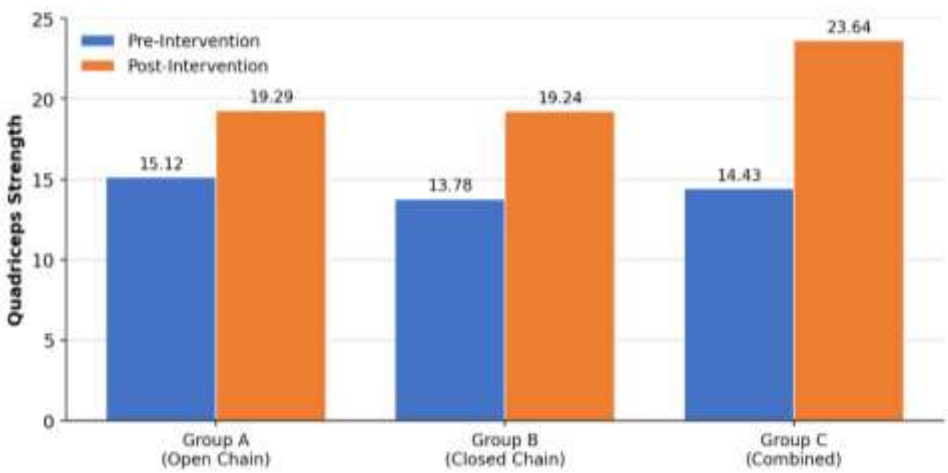

Figure 3. Mean quadriceps muscle strength (kg) pre and post-intervention by group.

DISCUSSION

This three arm RCT compared OKC, CKC and a combined OKC+CKC exercise protocols. All these intervention protocols were delivered along with a standardized conventional physiotherapy program. Their impact was to be checked on pain intensity and quadriceps muscle strength in patients with acute AKP over a duration of four weeks. The key finding is that combined OKC+CKC intervention protocol produced significantly greater improvements on both outcomes when compared to either exercise type used alone. Equally important, all three groups achieved clinically meaningful improvements; confirming that structured kinetic chain exercise therapy, regardless of kinetic chain type, is an effective approach for reducing acute AKP when delivered consistently and at an adequate dose.

The superiority of combined intervention protocol reflects mechanistic complements to OKC and CKC exercises. OKC exercises generate high levels of isolated and adequate quadriceps muscle activation by demanding unloaded distal limb movement against gravity or resistance; loading extensor system through its full contractile range (Adeel et al., 2024). This direct, targeted and specific stimulus is particularly important in AKP rehabilitation where VMO weakness and activation deficits are prominent and where patellar stabilization is a primary treatment goal. CKC exercises, on the other hand, promote co-contraction of entire lower limb kinetic chain as quadriceps, hamstrings, gluteals and hip stabilizers act simultaneously during weight bearing movements, providing a practical neuromuscular integration that more closely replicates functional demands (Kochar et al., 2024; Kamel et al., 2024). When both modalities are prescribed concurrently to a recipient, rehabilitative stimulus is widened to include both direct quadriceps overload as well as functional multi-joint neuromuscular training, generating additive effects which neither protocol can produce alone. This mechanistic reasoning is consistent with systematic evidence showing that combined hip and knee programs, which inherently blend OKC and CKC elements, outperform knee only protocols in PFP (Halabi et al., 2025; Fan et al., 2023).

The pain findings of the study carry particular clinical weight when they are interpreted against established MCID benchmarks. All three groups crossed NPRS MCID threshold of 1.74-2.0 points (Salaffi et al., 2004; Olsen et al., 2018). This ensures that each protocol produced genuine patient perceived pain relief. This finding alone is sufficiently clinically meaningful, as it validates the use of structured kinetic chain exercise, either OKC or CKC, as an effective pain management strategy in acute AKP. However, MCID is a minimum threshold and not an index of optimal outcomes. When stricter benchmark of ≥30% reduction from baseline, associated with patient perceived 'much better' status (Olsen et al., 2018), is applied; only Group C consistently exceeded it; achieving a 71.0% reduction compared to 37.1% and 42.8% in Groups A and B respectively. Clinically, this demonstrates that patients in combined group experienced near complete pain resolution, whereas those in single modality groups retained a meaningful residual pain post 4 week intervention. This distinction has true practical implications for patient satisfaction, return to activity/job and adherence to long term exercise.

Absence of a statistically significant difference between Groups A and B for both outcomes is a notable finding that can be a challenge to prevailing clinical assumptions. The conventional view in AKP rehabilitation has favored CKC exercises over OKC exercises on based on the fact that they better replicate functional, weight bearing movement patterns and engage hip stabilizer muscles which are often deficient in this specific population (Xie et al., 2023; Halabi et al., 2025). The present study results do not support this hierarchy when exercises are matched for volume, dosage and conventional therapy coadministration. At the dosage used in this study, OKC and CKC exercises appear to produce equivalent outcomes in terms of both outcomes i.e. pain and quadricep muscles' strength. This finding has an important practical implication; patients who are unable to safely perform weight bearing CKC exercises due to pain severity, balance deficits or any other comorbidity may be offered OKC exercises with a clinically equivalent therapeutic effect, expanding AKP rehabilitation options without clinical compromise.

The quadriceps strength findings duly reinforce and extend pain results. Strength gain in group C of +9.22 kg (63.9% relative increase) was nearly double than that of Group A (+4.17 kg; 27.6%) and substantially greater than Group B (+5.47 kg; 39.7%). This magnitude of strength gain within four weeks is clinically remarkable and points to a genuine synergistic effect rather than simply an additive benefit. Quadriceps weakness is one of most robustly documented impairments in AKP and its restoration is considered a primary mechanism through which pain is reduced and normal function is regained (Adeel et al., 2024; Kochar et al., 2024). The fact that combining kinetic chain protocols concurrently nearly doubles this outcome compared to OKC alone and produces substantially much larger gains than CKC alone provides a compelling evidence base for combined OKC+CKC prescription. These findings are consistent with Hong et al. (2023), who demonstrated that exercise programs which apply multiple movement strategies produced greater functional outcomes in PFP patients than those relying on a single exercise type.

Limitations and Recommendations

The study has several limitations that inform interpretation and generalizability of its findings. First, four-week intervention window; although being sufficient to demonstrate between-group differences; does not allow conclusions about long-term durability of effects. Up to 70-90% of AKP patients experience persistent or recurrent symptoms. Hence, whether superior outcomes observed in Group C are maintained at three or twelve months remains unknown (Barton et al., 2022). Second, treating physiotherapists were not blinded to interventions, introducing potential performance bias. Third, this study exclusively enrolled patients with acute AKP (≤3 months), which limits generalizability to chronic or recurrent presentations of AKP; a considerably larger proportion of this clinical population. Fourth, no any kinematic, electromyographic or biomechanical assessments were performed, leaving neuromotor mechanisms underlying observed outcomes speculative. Future research should investigate longer-term outcomes, effect on chronic AKP populations and addition of kinematic outcome measures to understand biomechanical pathways driving observed clinical improvements.

Clinical Implications

These findings have direct implications for clinical practice and future research. Physiotherapists involved in managing acute AKP should consider prescribing combined OKC and CKC exercise protocols as a preferred first line approach, rather than selecting one of the two modalities. The protocol evaluated here is pragmatic and practically deliverable in standard outpatient settings; four exercises per modality, four sets of 12 repetitions, three sessions per week on alternate days over four weeks.

CONCLUSION

This randomized controlled trial demonstrates that combined OKC and CKC exercises produce significantly greater improvements in pain intensity and quadriceps muscles' strength compared to either exercise type given alone in patients with acute AKP. All three groups achieved clinically meaningful improvements in outcomes but only combined OKC + CKC approach consistently exceeded the "much better" MCID threshold for pain as well as produced the largest absolute strength gains. These findings give a strong evidence base for integrating combined open and closed kinetic chain exercise protocols as a preferred first line rehabilitative approach in acute AKP.

Conflict of Interest

Authors declare no conflict of interest.

AI declaration

Generative AI tools were used to make figures given in this study.

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REFERENCES

1. Adeel, M., Lin, B. S., Chaudhary, M. A., Chen, H. C., & Peng, C. W. (2024). Effects of strengthening exercises on human kinetic chains based on a systematic review. Journal of Functional Morphology and Kinesiology, 9(1), 22. https://doi.org/10.3390/jfmk9010022
2. Adegoke, B. O., Sanya, A. O., Ogunlade, S. O., & Olagbegi, O. M. (2019). The effectiveness of open versus closed kinetic chain exercises on pain, function and range of motion in patients with knee osteoarthritis. Baltic Journal of Health and Physical Activity, 11(3), 39–52. https://doi.org/10.29359/BJHPA.11.3.05
3. Bartsch, A. anderson, F. L., Fredericson, M., & Sherman, S. L. (2024). Biomechanical and biological factors of sexual dimorphism in anterior knee pain: Current concepts. Journal of ISAKOS. https://doi.org/10.1016/j.jisako.2024.05.014
4. Barton, C. J., Lack, S., Hemmings, S., Tufail, S., & Morrissey, D. (2022). The 'best practice guide to conservative management of patellofemoral pain': Incorporating level 1 evidence with expert clinical reasoning. British Journal of Sports Medicine, 49(14), 923–934. https://doi.org/10.1136/bjsports-2014-093637
5. Constantinou, A., Mamais, I., Papathanasiou, G., Lamnisos, D., & Stasinopoulos, D. (2022). Comparing hip and knee focused exercises versus hip and knee focused exercises with the use of blood flow restriction training in adults with patellofemoral pain. European Journal of Physical and Rehabilitation Medicine, 58(2), 225–235. https://doi.org/10.23736/S1973-9087.22.06691-6
6. Bloomer, B. A., & Durall, C. J. (2015). Does the Addition of Hip Strengthening to a Knee-Focused Exercise Program Improve Outcomes in Patients With Patellofemoral Pain Syndrome?. Journal of sport rehabilitation, 24(4), 428–433. https://doi.org/10.1123/jsr.2014-0184
7. Georgoulis, J. D., Savvidou, O. D., Patras, K., Melissaridou, D., Hadjimichael, A. C., Papagelopoulos, P. J., & Georgoulis, A. D. (2024). Association of anterior knee pain with extension deficit after anterior cruciate ligament reconstruction: A systematic review. Orthopaedic Journal of Sports Medicine, 12(10). https://doi.org/10.1177/23259671241265840
8. Giles, L., Webster, K. E., McClelland, J., & Cook, J. L. (2017). Quadriceps strengthening with and without blood flow restriction in the treatment of patellofemoral pain: A double-blind randomised trial. British Journal of Sports Medicine, 51(23), 1688–1694. https://doi.org/10.1136/bjsports-2016-096329
9. Halabi, A. I., Spence, N., Narayan, A., Karnad, S. D., & Ottayil, Z. C. (2025). The efficacy of hip and knee muscles strengthening versus knee muscle strengthening alone in managing patellofemoral pain syndrome: A systematic review and meta-analysis. Musculoskeletal Care, 23(1), e70059. https://doi.org/10.1002/msc.70059
10. Hong, Q. M., Wang, H. N., Liu, X. H., Zhou, W. Q., Zhang, X., & Luo, X. B. (2023). Home-based exercise program and health education in patients with patellofemoral pain: A randomized controlled trial. BMC Musculoskeletal Disorders, 24(1), 921. https://doi.org/10.1186/s12891-023-07027-z
11. Huo, Z., Xu, C., Li, S., Niu, Y., & Wang, F. (2024). The thickness change ratio and preservation ratio of the infrapatellar fat pad are related to anterior knee pain following medial patellofemoral ligament reconstruction. Journal of Orthopaedic Surgery and Research, 19(1), 375. https://doi.org/10.1186/s13018-024-04853-2
12. Kamel, A. M., Ghuiba, K., Abd Allah, D. S., Fayaz, N. A., & Abdelkader, N. A. (2024). Effect of adding short foot exercise to hip and knee focused exercises in treatment of patients with patellofemoral pain syndrome: A randomized controlled trial. Journal of Orthopaedic Surgery and Research, 19(1), 200. https://doi.org/10.1186/s13018-024-04688-x

13. Kochar, S. S., Fating, T., & Patil, S. (2024). Efficacy of isometric exercises and somatosensory training for pain, proprioception and balance in runners with patellofemoral pain syndrome. Cureus, 16(3), e55838. https://doi.org/10.7759/cureus.55838
14. Kong, W., Wang, H., Cheng, L., & Ni, G. (2023). Comparing the effect of intermittent blood flow restriction training and high-load resistance training in patients with patellofemoral pain: Study protocol for a randomised trial. BMJ Open, 13(10), e073188. https://doi.org/10.1136/bmjopen-2023-073188
15. Li, S., Ng, W. H., Abujaber, S., & Shaharudin, S. (2021). Effects of blood flow restriction training on muscle strength and pain in patients with knee injuries. American Journal of Physical Medicine & Rehabilitation, 100(4), 337–344. https://doi.org/10.1097/PHM.0000000000001567
16. Xie, P., István, B., & Liang, M. (2023). The Relationship between Patellofemoral Pain Syndrome and Hip Biomechanics: A Systematic Review with Meta-Analysis. Healthcare, 11(1), 99. https://doi.org/10.3390/healthcare11010099
17. Menek, B., & Dansuk, E. (2025). Comparative efficacy of supervised, web-based and self-guided exercise interventions in women with patellofemoral pain syndrome. Medicina, 61(4), 731. https://doi.org/10.3390/medicina61040731
18. Moreira, V. M., da Silva, S. F., Hattori, W. T., & Dionisio, V. C. (2021). A comparison of the efficacy of nonweight-bearing and weight-bearing exercise programmes on function and pain pressure thresholds in knee osteoarthritis: A randomised study. European Journal of Physiotherapy, 23(3), 171–178. https://doi.org/10.1080/21679169.2019.1663928
19. Nahayatbin, M., Ghasemi, M., Rahimi, A., Khademi-Kalantari, K., Naimi, S. S., & Tabatabaee, S. M. (2018). Effects of routine physiotherapy alone and in combination with either Tai Chi or closed kinetic chain exercises on knee osteoarthritis. Iranian Red Crescent Medical Journal, 20(4).
20. Ng, W. H., Jamaludin, N. I., Sahabuddin, F. N. A., Ab Rahman, S., Ahmed Shokri, A., & Shaharudin, S. (2022). Comparison of the open kinetic chain and closed kinetic chain strengthening exercises on pain perception and lower limb biomechanics of patients with mild knee osteoarthritis: A randomized controlled trial protocol. Trials, 23(1), 315. https://doi.org/10.1186/s13063-022-06261-3
21. Olsen, M. F., Bjerre, E., Hansen, M. D., Tendal, B., Hilden, J., & Hróbjartsson, A. (2018). Minimum clinically important differences in chronic pain vary considerably by baseline pain and methodological factors: Systematic review of empirical studies. Journal of Clinical Epidemiology, 101, 87–106. https://doi.org/10.1016/j.jclinepi.2018.05.007
22. Roos, E. M. (2024). 30 years with the Knee Injury and Osteoarthritis Outcome Score (KOOS). Osteoarthritis and Cartilage, 32(4), 421–429. https://doi.org/10.1016/j.joca.2023.10.002
23. Salaffi, F., Stancati, A., Silvestri, C. A., Ciapetti, A., & Grassi, W. (2004). Minimal clinically important changes in chronic musculoskeletal pain intensity measured on a numerical rating scale. European Journal of Pain, 8(4), 283–291. https://doi.org/10.1016/j.ejpain.2003.09.004
24. Smith, B. E., Selfe, J., Thacker, D., Hendrick, P., Bateman, M., Jane, M., Mikolajewski, T., & Logan, P. (2018). Incidence and prevalence of patellofemoral pain: A systematic review and meta-analysis. PLOS ONE, 13(1), e0190892. https://doi.org/10.1371/journal.pone.0190892
25. Vikhe, C. S., Ramteke, S. U., & Hullumani, S. (2024). Effect of physiotherapy interventions on pain management, function and quality of life in patellofemoral pain syndrome: A systematic review protocol. PLOS ONE, 19(12), e0312279. https://doi.org/10.1371/journal.pone.0312279
26. Dong, R., Wu, Y., Xu, S., Zhang, L., Ying, J., & Jin, H. (2018). Is aquatic exercise more effective than land-based exercise for knee osteoarthritis? Medicine, 97(52). https://doi.org/10.1097/MD.0000000000013823