

Effects of Open Chain, Closed Chain and Combined Exercises on Arterial Occlusion Pressure and Knee Functional Outcomes in Patients with Anterior Knee Pain: A Randomized Controlled Trial

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doi: 10.22442/jlumhs.2026.01628

ABSTRACT

OBJECTIVE: To observe the effects of open kinetic chain (OKC) and closed kinetic chain (CKC), merge OKC+CKC exercise on arterial occlusion pressure (AOP) and observe knee functional outcomes with acute anterior knee pain (AKP) in patients.

METHODOLOGY: This three-arm, parallel-group randomized controlled trial was conducted from 1 October 2025 to 5 July 2026 at Departments of Rehabilitation Sciences, Ziauddin Hospital, Karachi, Pakistan. 96 patients with acute AKP aged 18-40 years were recruited by non-probability consecutive sampling and randomized to three groups as: Participants were equally distributed into three groups: Group A (OKC; n = 32), Group B (CKC; n = 32), and Group C (combined OKC and CKC; n = 32). All intervention groups received conventional physiotherapy in addition to assigned intervention, three days per week, four sets of 12 repetitions for 4 weeks. Primary outcomes were AOP and knee function. Data were analyzed using repeated-measures ANOVA in SPSS version 26.0.

RESULTS: The significant TimeGroup interactions were found for AOP ($F(2, 93) = 59.705$, $p < 0.001$) and all KOOS subscales and total score (all $p < 0.001$). Group C produced greatest AOP increase (+16.94 mmHg) and KOOS total improvement (+48.69 points). For Sport/Recreation and Quality of Life subscales, all three groups differed significantly, with Group B superior to Group A ($p < 0.05$); for KOOS total, all pairwise comparisons were significant ($p < 0.001$).

CONCLUSION: Results of combined OKC+CKC exercises produced greatest advancement in AOP and knee function. CKC was superior to OKC in sport/recreation and quality of life. Clinicians should consider combined kinetic chain protocols for a comprehensive rehabilitation of acute AKP.

KEY WORDS: Anterior knee pain; Arterial occlusion pressure; Open kinetic chain exercise; Closed kinetic chain exercise; Patellofemoral pain; Randomized controlled trial; Functional outcomes.

INTRODUCTION

Anterior knee discomfort or pain (AKP), known as patellofemoral pain (PFP), is characterized by an insidious onset of pain in front of knee that is consistently provoked by loading activities such as stair climbing, squatting, jumping, running and prolonged sitting.¹ It is amongst most frequently encountered musculoskeletal complaints across clinical and sporting contexts, with reported prevalence in adolescents ranging between 20-40% and it is especially common in young and physically active individuals.^{2,3} AKP is not merely a pain; it imposes a variety of functional burden, with patients reporting limitations in activities of daily living, reduced participation in sport and recreation and deterioration in health-related quality of life.⁴ These functional consequences are often disproportionate to severity of pain and may persist after pain has partially resolved, making condition a frequent reason for seeking care.

The functional impairment in AKP comes from a convergence of local and proximal factors, including quadriceps weakness and deficits in external rotator and hip abductor strength that promote excessive femoral adduction as well as internal rotation during weight bearing tasks. Beyond joint mechanics, emerging evidence reports vascular and neurovascular changes at patella femoral joint, including impaired local hemodynamics and perfusion, which may be reflected in measurable changes in Arterial occlusion pressure (AOP) during rehabilitation.⁵ AOP, defined as minimum magnitude of pressure required to fully occlude/block arterial blood flow in a limb, is influenced by limb muscle mass, vascular compliance and neuromuscular activity and changes following exercise are considered to reflect adaptations in local vascular tone and muscular conditioning, offering a physiologically meaningful index of neuromuscular and vascular response.⁶

Exercise therapy is first-line intervention for AKP. Within it, OKC exercises, such as straight-leg raises and seated knee extensions, are primarily used to strengthen the quadriceps muscles directly, while CKC exercises such as wall slides, step-ups and terminal knee extensions provide functional neuromuscular training that involves hip stabilizers and replicates weight bearing movement patterns. Meta-analyses of combined hip and knee programs suggest that combining loading approaches produces superior outcomes to knee only protocols, potentially through additive neuromuscular and biomechanical mechanisms.^{7,8} However, few studies have directly compared OKC, CKC, and combined OKC+CKC exercise programs using both comprehensive patient-reported functional measures and a physiological parameter such as AOP. To find out this gap, the present study showed that whether the combined OKC+CKC intervention would result in greater improvements in AOP and all KOOS domains compared with either exercise approach alone. It also examined whether OKC and CKC training would demonstrate distinct effects across different functional domains.

METHODOLOGY

Study Design, Setting and Duration: This three-arm, parallel-group randomized controlled trial was conducted from 1st October 2025 to 5th July 2026, at Departments of Rehabilitation Sciences, Ziauddin Hospital, Karachi, Pakistan, across its three campuses at Kemari, North Nazimabad and Clifton. Study was conducted with alignment and guide lines of CONSORT. After getting Ethical approval Ethical approval was obtained from the ERC of Ziauddin University (Ref. No. 10700725 DAPT; dated 23rd September 2025), and the study was conducted in accordance with the principles of the Declaration of Helsinki Informed consent was taken from the participant before enrolment in the study.

Sampling and Participants: Patients were recruited using a non-probability consecutive sampling technique. In present study both male and female patients between 18 and 40 years of age with a clinical diagnosis of acute anterior knee pain (AKP), defined as pain located at the anterior aspect of the knee with a duration of less than three months were included. To be eligible, symptoms had to be aggravated by at least one weight-bearing or loading activity, such as stair climbing, squatting, prolonged sitting, or running. Patients were excluded if they had undergone any kind of knee surgery within the previous 12 months or any history of malignancy, radiculopathy, inflammatory joint disease, knee infection, recurrent patellar dislocation, patellar subluxation, or knee instability. Participant who received any physical therapy for the current episode of knee pain or had any medical condition that could compromise the safety of exercise participation were also excluded.

Sample Size: The sample size was calculated by using Open Epi on the basis effect size reported in a previous comparable clinical trial investigating kinetic-chain exercises in patients with knee pain. As statistical power of 80% and a significance level of 5% ($\alpha = 0.05$), the minimum sample was 29 participants for each group. To compensate for an anticipated 10% loss to follow-up or attrition, the sample size was increased up to 32 in each group. Accordingly, the study planned to recruit a total of 96 participants across the three groups.

Randomization, Allocation Concealment and Blinding: Group assignment was carried out through sequentially numbered opaque sealed envelopes (SNOSE), which were prepared by a researcher who did not take part in recruitment or data collection. The allocation remained concealed until each participant's baseline assessment was completed. Throughout the trial, both the outcome assessors and the study statistician remained blinded of group assignments and participants were kept blinded to comparative arms of study. Blinding of treating physiotherapists was not feasible, since delivering exercise interventions inevitably reveals which protocol is being applied.

Interventions: Participants in all three groups underwent a four-week exercise program, following of three sessions per week on alternate days. Each session lasted approximately 30 minutes, with each exercise performed for four sets of 12 repetitions.

Interventions at all three sites were delivered by the same physiotherapist to ensure the exactly same protocol followed at all sites. Standardized conventional physiotherapy was provided before each session: TENS (10 minutes at 7 Hz, pulse rate > 100 pulses per second)⁹ and hot pack application (10 minutes at 37-40°C). Each session comprised a 5-minute warm-up (calf, hamstring and quadriceps stretches) and a 5-minute cool-down (slow walking).

Group A (OKC): (a) Straight leg raise; from supine position, participant raised extended leg approximately 20 cm off the surface while maintaining knee locked in complete extension; (b) long arc quad ; seated upright, participant straightened knee to full extension, sustained the position for 5-10 seconds and then returned it under control to 90° of flexion; (c) Hip abduction; lying on side, upper leg was raised as far as comfortably possible while hip was kept in neutral alignment; (d) Hip

adduction; in the same sidelying position, lower leg was lifted through adductor contraction whereas upper leg rested flexed at hip.

Group B (CKC): (a) Standing terminal knee extension; beginning at 90° of knee flexion, participant extended knee against resistance of an elastic band; (b) Wall slide; with back supported against a wall, participant descended into 30-40° of knee flexion, held the position for 5 seconds and rose back to standing; (c) Forward step-up; affected limb was placed onto a platform and body weight fully transferred onto it, followed by a controlled descent; (d) Lateral step-up; same movement performed to side, stepping laterally onto the platform.

Group C (OKC+CKC): This group went through all OKC exercises from Group A as well all CKC exercises from Group B, performed concurrently at same dosage in each single session.

Outcome Measures: Both primary outcomes were assessed at baseline and at 4 weeks by a blinded assessor who was same at all three sites. Arterial Occlusion Pressure (AOP) was measured in millimeters of mercury using Doppler ultrasound, representing minimum limb cuff pressure required to completely occlude arterial blood flow, determined by inflating a pneumatic cuff at proximal thigh while monitoring distal arterial signal with a handheld Doppler probe. Knee Injury and Osteoarthritis Outcome Score (KOOS) is a validated, self-administered questionnaire assessing five domains: Symptoms and Stiffness, Pain, Function in Activities of Daily Living, Function in Sport/Recreation and Knee-Related Quality of Life. Each subscale is scored from 0 to 100, with higher scores indicating better function and a composite total score was calculated as mean of five subscales.

Missing Data and Statistical Analysis: One participant from group A and one from group C withdrew one week before completion. Missing values for them were estimated by multiple imputation method; using baseline values as per group allocation, with 5 number of imputations through monotone two way interaction method using Predictive mean matching (PPM) model; and all 96 participants were included in final analysis on an intention-to-treat (ITT) basis. Baseline characteristics were summarized using frequencies for categorical variables while means (M) and standard deviations (SD) for continuous variables. Normality was checked with Kolmogorov-Smirnov and Shapiro-Wilk tests and homogeneity of variance using Levene's test. A repeated-measures ANOVA was applied for each outcome, keeping Group as between-subjects factor and Time as within-subjects factor. Time*Group interaction was primary inferential test applied. For between-group comparisons, Bonferroni post hoc corrections were applied. Data was analyzed using SPSS version 26.0, keeping level of significance at $p < 0.05$.

RESULTS

The CONSORT flow diagram is presented in Figure-1. Baseline demographic and clinical characteristics were comparable across groups, with no statistically significant between-group differences (Table-I). Baseline KOOS total scores ranged from 29.63 to 32.03, reflecting moderate to severe functional limitation at enrolment and all variables were normally distributed (Kolmogorov-Smirnov $p > 0.05$).

Table-I: Baseline Characteristics of All Groups

Characteristic	Group A (OKC) (n = 32)	Group B (CKC) (n = 32)	Group C (OKC+CKC) (n = 32)	p-value
Age (years), Mean $\pm$ SD	27.06 $\pm$ 2.96	27.13 $\pm$ 2.94	26.72 $\pm$ 2.91	0.832
Gender, n (%) (Male)	17 (53.1)	16 (50.0)	16 (50.0)	0.959
Gender, n (%) (Female)	15 (46.9)	16 (50.0)	16 (50.0)	0.865
AOP (mmHg), Mean $\pm$ SD	122.97 $\pm$ 5.50	123.72 $\pm$ 4.79	123.25 $\pm$ 4.83	0.846
KOOS Total, Mean $\pm$ SD	29.63 $\pm$ 3.54	30.41 $\pm$ 3.73	32.03 $\pm$ 4.23	0.061

Note. SD = Standard Deviation; OKC = open kinetic chain; CKC = closed kinetic chain; AOP = arterial occlusion pressure; KOOS = Knee Injury and Osteoarthritis Outcome Score.

All groups demonstrated statistically significant improvements in AOP and all KOOS subscales and total score over intervention, with significant Time*Group interactions for all outcomes (all $p < 0.001$). Pre and post-intervention means, changes results are presented in Table-II and between-group post hoc comparisons in Table-III.

Arterial Occlusion Pressure: AOP increased in all groups (Table-II; Figure-2). Post hoc analysis showed that Group C achieved a significantly greater AOP increase than Group A, while differences between Groups A and B and between Groups B and C, were not significant (Table-III). Group C thus produced a vascular and neuromuscular adaptation distinguishable from OKC only protocol, with CKC only protocol occupying an intermediate locus.

KOOS Subscales and Total Score: For Symptoms and Stiffness, Pain and Function-ADL, Groups A and B did not differ significantly, while Group C was significantly superior to both. For Function-Sport/Recreation and Quality of Life, all three groups differed significantly, with a confirmed hierarchy of Group C > Group B > Group A. For KOOS total scores, all pairwise comparisons were significant, confirming a consistent three-level hierarchy (Table-III; Figure-3). All three groups exceeded established KOOS minimal clinically important difference (MCID) of 8-12 points across all subscales; Group C exceeded it most substantially and was only group to achieve a KOOS total improvement above 40 points.

Table-II: Pre and Post-Intervention Means, Changes and ANOVA Results for All Outcomes

Outcome	Group	Pre M (SD)	Post M (SD)	Change	F (Time)	F (Time×Grp)	P
AOP (mmHg)	Group A (OKC)	122.97 (5.50)	131.88 (4.37)	+8.91	1663.374	59.705	<0.001
	Group B (CKC)	123.72 (4.79)	135.28 (5.41)	+11.56			
	Group C (Combined)	123.25 (4.83)	140.19 (4.34)	+16.94			
KOOS Symptoms	Group A (OKC)	55.88 (9.71)	69.03 (8.84)	+13.15	261.410	12.494	<0.001
	Group B (CKC)	54.16 (9.11)	73.81 (9.17)	+19.66			
	Group C (Combined)	57.56 (11.19)	86.16 (6.01)	+28.59			
KOOS Pain	Group A (OKC)	25.22 (8.34)	62.22 (7.65)	+37.00	1330.317	24.145	<0.001
	Group B (CKC)	26.81 (8.93)	66.22 (8.08)	+39.41			
	Group C (Combined)	27.78 (9.44)	83.69 (7.63)	+55.91			
KOOS Function-ADL	Group A (OKC)	32.19 (8.79)	70.19 (9.19)	+38.00	1249.466	12.867	<0.001
	Group B (CKC)	33.72 (8.86)	69.16 (8.44)	+35.44			
	Group C (Combined)	34.84 (7.98)	83.78 (7.74)	+48.94			
KOOS Function-Sport	Group A (OKC)	16.25 (6.04)	55.28 (7.07)	+39.03	1400.625	16.415	<0.001
	Group B (CKC)	18.28 (7.66)	61.34 (9.50)	+43.06			
	Group C (Combined)	18.78 (7.64)	74.31 (9.11)	+55.53			
KOOS QoL	Group A (OKC)	18.47 (6.77)	51.28 (11.73)	+32.81	1180.653	25.184	<0.001
	Group B (CKC)	19.16 (7.75)	61.13 (8.22)	+41.97			
	Group C (Combined)	21.22 (9.04)	75.75 (8.92)	+54.53			
KOOS Total	Group A (OKC)	29.63 (3.54)	61.56 (3.84)	+31.94	5386.128	90.847	<0.001
	Group B (CKC)	30.41 (3.73)	66.38 (2.84)	+35.97			
	Group C (Combined)	32.03 (4.23)	80.72 (3.48)	+48.69			

Note. AOP = arterial occlusion pressure; KOOS = Knee Injury and Osteoarthritis Outcome Score; ADL = Activities of Daily Living; QoL = Quality of Life; M = mean; SD = standard deviation.

Table-III: Post Hoc (Bonferroni) Comparisons: BetweenGroup Mean Differences

Outcome	Comparison	Mean Diff.	SE	p	Sig.
AOP	A vs. B	-2.078	1.165	0.233	No
AOP	A vs. C	-4.297	1.165	0.001	Yes
AOP	B vs. C	-2.219	1.165	0.180	No
KOOS Symptoms	A vs. B	-1.531	1.677	1.000	No
KOOS Symptoms	A vs. C	-9.406	1.677	<0.001	Yes
KOOS Symptoms	B vs. C	-7.875	1.677	<0.001	Yes
KOOS Pain	A vs. B	-2.797	1.479	0.185	No
KOOS Pain	A vs. C	-12.016	1.479	<0.001	Yes
KOOS Pain	B vs. C	-9.219	1.479	<0.001	Yes
KOOS Function-ADL	A vs. B	-0.250	1.591	1.000	No
KOOS Function-ADL	A vs. C	-8.125	1.591	<0.001	Yes
KOOS Function-ADL	B vs. C	-7.875	1.591	<0.001	Yes

Outcome	Comparison	Mean Diff.	SE	p	Sig.
KOOS Function-Sport	A vs. B	-4.047	1.293	0.007	Yes
KOOS Function-Sport	A vs. C	-10.781	1.293	<0.001	Yes
KOOS Function-Sport	B vs. C	-6.734	1.293	<0.001	Yes
KOOS QoL	A vs. B	-5.266	1.599	0.004	Yes
KOOS QoL	A vs. C	-13.609	1.599	<0.001	Yes
KOOS QoL	B vs. C	-8.344	1.599	<0.001	Yes
KOOS Total	A vs. B	-2.797	0.637	<0.001	Yes
KOOS Total	A vs. C	-10.781	0.637	<0.001	Yes
KOOS Total	B vs. C	-7.984	0.637	<0.001	Yes

Note. SE = Standard Error. A = Group A (OKC); B = Group B (CKC); C = Group C (combined OKC+CKC).

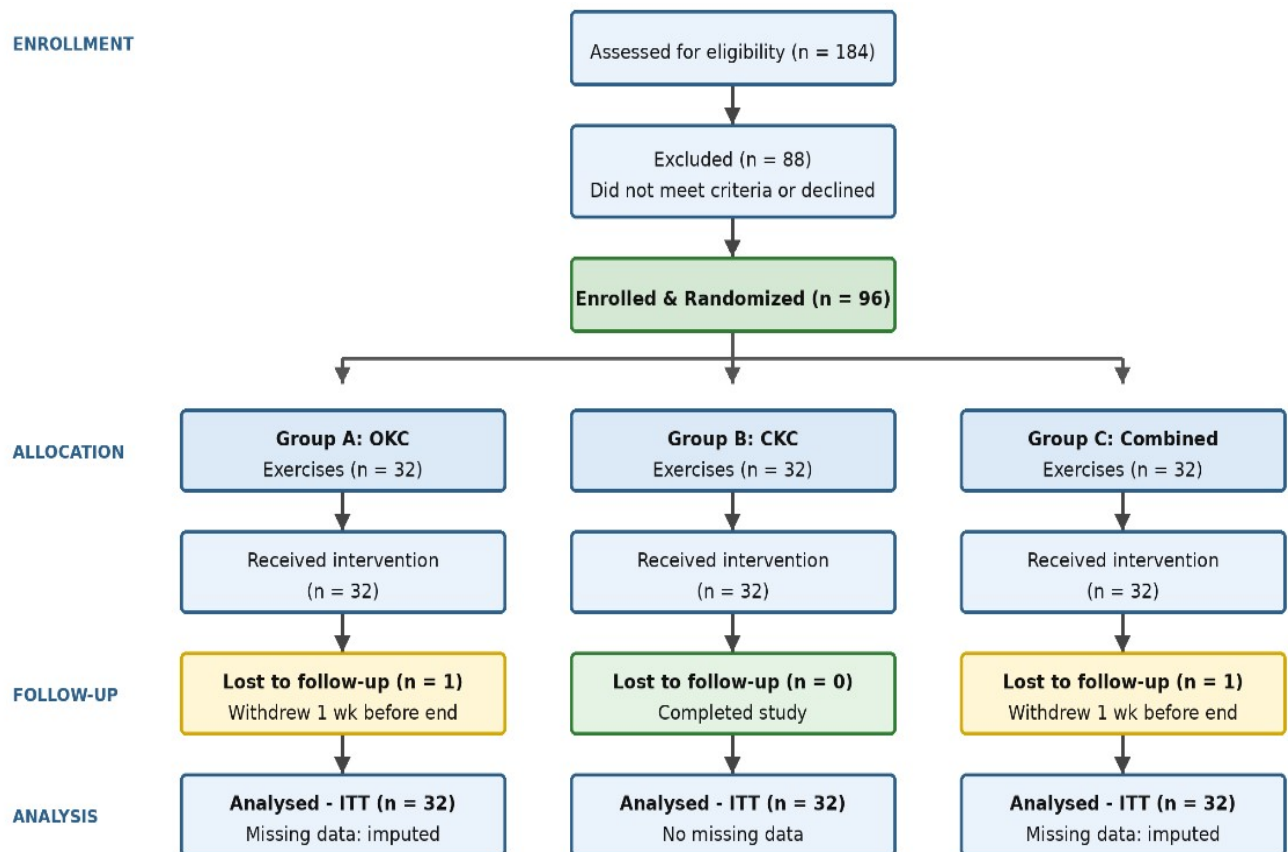


Figure 1: CONSORT flow diagram

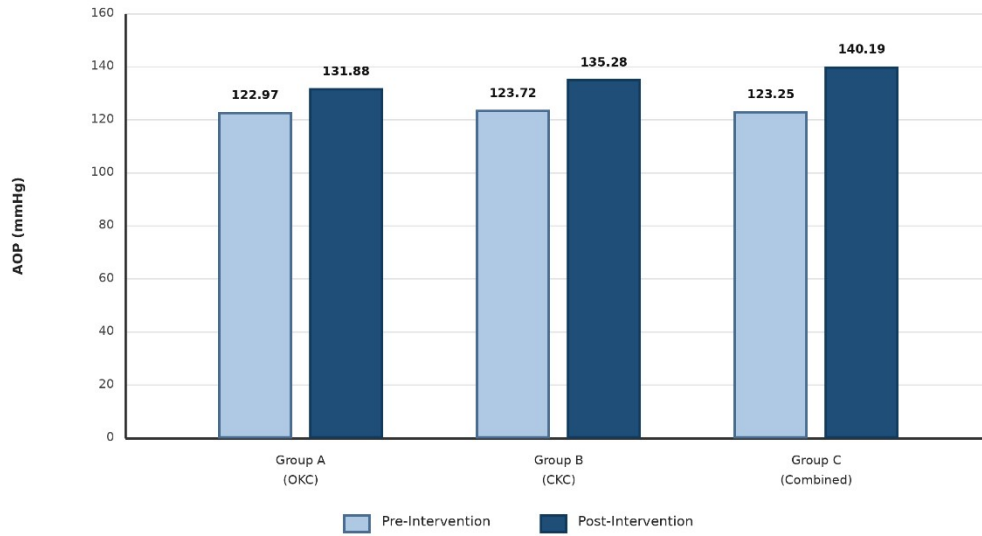


Figure 2: Mean AOP (mmHg) pre- and post-intervention by group.

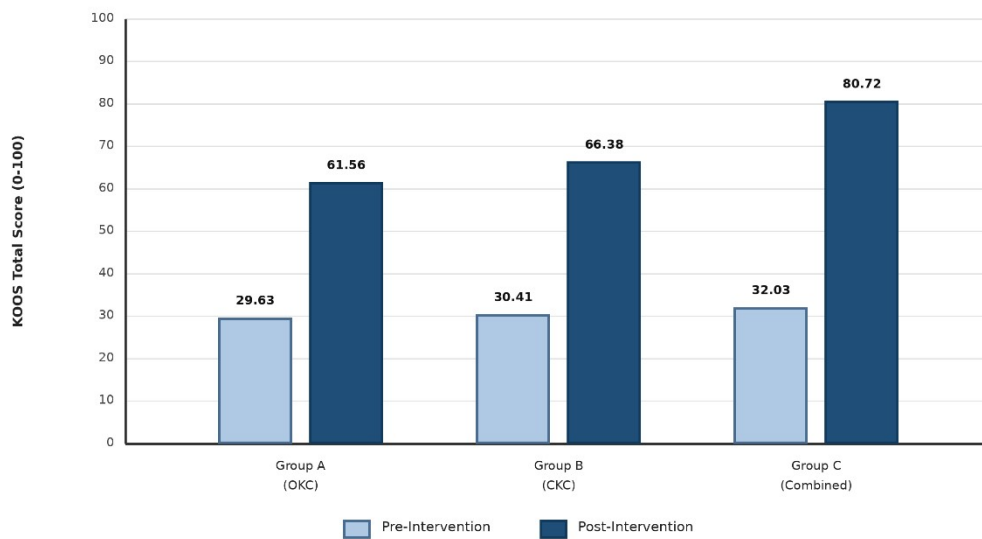


Figure 3: Mean KOOS total score pre- and post-intervention by group

DISCUSSION

This trial examined effects of OKC, CKC and combined OKC+CKC exercises on AOP and knee-related functional outcomes in patients with acute AKP. Three principal findings emerged in the results. First, combined protocol produced superior outcomes across all measures, with statistically significant differences on most compared with single-modality protocols. Second, post hoc pattern was not uniform: for sport/recreation function and quality of life, CKC exercises were significantly superior to OKC, a domain-specific advantage not seen for symptoms, pain or ADL. Third, all three protocols achieved clinically meaningful improvements across every KOOS subscale, confirming that structured kinetic chain exercises, regardless of kinetic chain exercise type used, is an effective rehabilitation strategy for acute AKP.

The superiority of combined protocol is consistent with mechanistic rationale underlying kinetic chain rehabilitation. OKC exercises provide direct, isolated quadriceps loading through a full range of motion, targeting vastus medialis obliquus atrophy and activation deficits that contribute to patellar maltracking.¹⁰ CKC exercises engage hip stabilizers, hamstrings and gluteal muscles in coordinated weight-bearing co-contraction, correcting proximal neuromuscular deficits, particularly hip abductor weakness, that generate abnormal patellofemoral contact forces during functional activities.^{11,12} Because these two modalities address complementary components of extensor mechanism and wider kinetic chain, combining them generates a rehabilitation stimulus that spans full functional spectrum, from symptom reduction to sport participation, which multidimensional structure of KOOS is well suited to capture. This is coherent with meta-analyses evidence that adding hip focused and multi joint work to knee focused programs improves outcomes.^{13,16}

The domain specific advantage of CKC over OKC in Sport/Recreation ($p = 0.007$) and Quality of Life ($p = 0.004$) sub scales is a particularly informative finding. In contrast to symptoms, pain and basic ADL, where two single modality groups were statistically equivalent, these two sub scales shown significant differences between them. This divergence is mechanistically coherent; sport and recreational activities demand dynamic, multi joint neuromuscular coordination, balance and reactive lower limb stabilization, precisely capacities trained by CKC exercises through their weight-bearing, multi-segment movement patterns.¹⁴ OKC exercises, while effective for isolated quadriceps strengthening, do not train functional co-contraction and dynamic joint stabilization strategies required for higher demand activities. This pattern is consistent with broader literature comparing loading strategies, in which closed chain and weight bearing exercises tend to confer advantages on higher order functional and quality of life outcomes even where pain relief is comparable.^{14,17} As quality of life in AKP is closely related to a patient's perceived capacity to participate in physical activity,⁴ it is plausible that those trained with CKC exercises, who improved their functional movement confidence, reported greater quality of life gains. Clinically, this suggests that where resources permit only one exercise type, CKC may be preferable, not because it produces greater pain relief or ADL improvement, but because it more effectively addresses higher order functional aspects most relevant to quality of life.

The AOP findings add a complementary physiological dimension to functional results. AOP reflects inter play of systemic blood pressure, limb muscle mass and vascular compliance. Increases in AOP following exercise are thought to indicate adaptations in local musculature and vascular tone.⁶ This is of particular interest in AKP given emerging evidence of impaired patellar hemodynamics and vascular insufficiency in condition,⁵ which raises possibility that exercise induced vascular adaptation is a relevant target of rehabilitation. The finding that only Group C produced a statistically significant AOP increase compared with Group A, while Group B occupied an intermediate position, suggests that combined stimulus across both kinetic chains generates

sufficient neuromuscular and vascular loading to produce a measurable physiological adaptation. Modest magnitude of AOP change across groups (7-14% relative increase) should not be read as a lack of effect; rather, it reflects inherently -constrained range of AOP variability in this population and it is consistent with broader literature on low load blood flow restricted and weight bearing training in knee rehabilitation, in which meaningful neuromuscular adaptation can occur without large changes in occlusion pressure.^{15,18,19}

The clinical relevance of these findings is best appreciated against KOOS MCID. Established interpretation thresholds for KOOS change place MCID for individual subscales at approximately 8-12 points.²⁰ All three groups exceeded this value across all subscales, confirming a genuine, patient acknowledged benefit in every protocol. However, between-group differences become clinically salient when absolute changes are compared: Group C's KOOS total improvement of +48.69 points, against +31.94 and +35.97 in Groups A and B respectively, represents not merely a larger effect but a categorically greater shift along functional spectrum, moving patients from moderate to severe limitation toward near normal function within 4 weeks. Quality of Life subscale also needs comment, as it showed lowest absolute post-intervention scores across all groups (Group A 51.28; Group B 61.13; Group C 75.75). persistence of relatively reduced QoL, particularly in Group A, suggests that 4 weeks of OKC exercise alone may be insufficient to restore health related quality of life to near normal levels, which may be especially relevant for younger, physically active patients for whom recreational participation is central to wellbeing. These findings extend existing evidence on kinetic chain exercises, most of which has compared single modalities in isolation or added hip work to knee focused programs,^{7,8,16} by demonstrating within a single controlled design that concurrent OKC and CKC training is superior to either alone and by situating that superiority alongside a physiological index of adaptation. They are consistent with and build upon, prior comparative work on kinetic chain loading in knee conditions.²¹

LIMITATIONS

Several limitations apply. These include a 4-week intervention window without long term follow-up, inability to blind treating therapists, restriction to acute AKP, a single baseline AOP measurement and absence of kinematic or electromyographic outcomes. In addition, greater total exercise volume in Group C (eight exercises versus four) is an uncontrolled variable that may partly account for superior functional outcomes through a dose response mechanism and this should be addressed in future dose matched designs. Moreover, age range of 18-40 years and AKP of less than three months also limits its generalizability to wider populations of other age range or a pain of longer duration.

CONCLUSION

Combined OKC and CKC exercises produced significant improvements in AOP and all KOOS subscales compared with protocol in patients with acute AKP. All three protocols achieved clinically significant improvements, exceeding established KOOS minimal clinically important difference thresholds across all domains. A domain-specific hierarchy emerged for sport/recreation function and quality of life, where CKC exercises were significantly superior to OKC, aligning with functional demands of higher-level physical activities.

RECOMMENDATIONS

These results support prescription of combined kinetic chain exercise as preferred approach for comprehensive AKP rehabilitation, while indicating that CKC exercises should be prioritized when combined protocols are not feasible, particularly for patients with recreational or sport-related functional goals. Future research should investigate dose-matched protocols and incorporate longer follow-up to determine whether CKC advantage in sport and quality-of-life domains is maintained or amplified over extended rehabilitation.

Ethical Approval: Ethical approval for this study was obtained from ERC of Ziauddin University with Ref. # 10700725DAPT, dated 23-09-2025). All participants signed written informed consent before participation and study duly followed guidelines of the Declaration of Helsinki.

Conflict of interest: There is no conflict of interest between the authors.

Financial Disclosure / Grant Approval: No funding agency was involved in this research.

Data Sharing Statement: The corresponding author can provide the data proving the findings of this study on request. Privacy or ethical restrictions bound us from sharing the data publicly.

AUTHOR CONTRIBUTION

Khan DA: Literature search, study design, concept, data collection

Kazmi SAM: Supervision, study designing, data interpretation

Rafi S: Data analysis, revision of manuscript

Khan AA: Drafting, data interpretation, preparation and final reviewing of manuscript

REFERENCES

1. Vikhe CS, Ramteke SU, Hullumani S. Effect of physiotherapy interventions on pain management, function and quality of life in patellofemoral pain syndrome: a systematic review protocol. *PLoS One*. 2024; 19(12): e0312279.
2. Xu J, Cai Z, Chen M, Wang X, Luo X, Wang Y. Global research trends and hotspots in patellofemoral pain syndrome from 2000 to 2023: a bibliometric and visualization study. *Front Med (Lausanne)*. 2024; 11: 1370258.
3. Sonesson S, Rosengren BE, Karlsson MK, Gauffin H. Patellofemoral pain in young people — a challenge for primary health care. *J OrthopSurg Res*. 2021; 16(1): 456.
4. Roos EM. 30 years with Knee Injury and Osteoarthritis Outcome Score (KOOS). *Osteoarthritis Cartilage*. 2024; 32(4): 421-9.
5. Ophhey MJ, Westerweel A, van Oort M, van den Berg R, Kerkhoffs GMMJ, Tak IJR. Impaired hemodynamics of patella in patients with patellofemoral pain: a case-control study. *J ExpOrthop*. 2024; 11(1): e12009.
6. de Queiros VS, Rolnick N, Wilde P, de Melo A, Cabral BG, Dantas PM. Measuring arterial occlusion pressure for training with blood flow restriction: a scoping review and recommendations for measurement. *Sport Sci Health*. 2024; 20(2): 259-72.
7. Fan Y, Bai D, Cheng C, Tian G. Does addition of hip strengthening to a knee-focused exercise program improve outcomes in patients with patellofemoral pain syndrome? *Ann Med*. 2023; 55(2): 2240329.
8. Halabi AI, Spence N, Narayan A, Karnad SD, Ottayil ZC. Efficacy of hip and knee muscle strengthening versus knee muscle strengthening alone in managing patellofemoral pain syndrome: a systematic review and meta-analysis. *Musculoskeletal Care*. 2025; 23(1): e70059.
9. Vance CG, Rakel BA, Blodgett NP, DeSantana JM, Amendola A, Zimmerman MB, et al. Effects of transcutaneous electrical nerve stimulation on pain, pain sensitivity, and function in people with knee osteoarthritis: a randomized controlled trial. *Phys Ther*. 2012; 92(7): 898–910.
10. Adeel M, Lin BS, Chaudhary MA, Chen HC, Peng CW. Effects of strengthening exercises on human kinetic chains based on a systematic review. *J FunctMorpholKinesiol*. 2024; 9(1): 22.
11. Liao CD, Tsao JY, Lin LF, Huang SW, Ku JW, Chou LC, et al. Relationship between patellofemoral pain syndrome and hip biomechanics: a systematic review with meta-analysis. *Healthcare (Basel)*. 2023; 11(1): 99.
12. Kamel AM, Ghuiba K, Abd Allah DS, Fayaz NA, Abdelkader NA. Effect of adding short foot exercise to hip and knee focused exercises in treatment of patients with patellofemoral pain syndrome: a randomized controlled trial. *J OrthopSurg Res*. 2024; 19(1): 200.
13. Nunes GS, Pellenz MM, Piussi JB, Wageck B, Signori LU, Solner MW, et al. Which factors correlate with muscle strength capacity in people with patellofemoral pain? A systematic review with meta-analysis. *Knee*. 2026; 60: 104358.
14. Kochar SS, Fating T, Patil S. Efficacy of isometric exercises and somatosensory training for pain, proprioception and balance in runners with patellofemoral pain syndrome. *Cureus*. 2024; 16(3): e55838.
15. Constantinou A, Mamais I, Papathanasiou G, Lamnisis D, Stasinopoulos D. Comparing hip and knee focused exercises versus hip and knee focused exercises with use of blood flow restriction training in adults with patellofemoral pain. *Eur J Phys Rehabil Med*. 2022; 58(2): 225-35.

16. Michael HJ, Pham HD, Li LSK, Semciw AI, Scholes MJ, Hannington M, et al. efficacy of closed versus open kinetic chain exercise in knee osteoarthritis: a systematic review and meta-analysis. *Physiother Res Int*. 2025; 30(4): e70105.
17. Moreira VM, da Silva SF, Hattori WT, Dionisio VC. A comparison of efficacy of non-weight-bearing and weight-bearing exercise programs on function and pain pressure thresholds in knee osteoarthritis: a randomised study. *Eur J Physiother*. 2021; 23(3): 171-8.
18. Kong W, Wang H, Cheng L, Ni G. Comparing 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*. 2023; 13(10): e073188.
19. Scott BR, Loenneke JP, Slattery KM, Dascombe BJ. Blood flow restriction exercise: mechanisms, applications and future perspectives. *J Sci Med Sport*. 2023; 26(4): 215-23.
20. Ingelsrud LH, Terluin B, Thorlund JB, Pedersen JR, Roos EM. Knee Injury and Osteoarthritis Outcome Score interpretation thresholds at 3 and 12 months after arthroscopic meniscal surgery. *J Orthop Sports Phys Ther*. 2023; 53(11): 685-702.
21. Ng WH, Jamaludin NI, Sahabuddin FNA, Ab Rahman S, Ahmed Shokri A, Shaharudin S. Comparison of 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*. 2022; 23(1): 315.