

INFLUENCE OF OPEN VS. CLOSED KINETIC CHAIN EXERCISES ON JOINT STABILITY AND PROPRIOCEPTION IN ELDERLY POPULATIONS

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Abstract

Background: Ageing is associated with declines in muscle strength, neuromuscular control, balance, and proprioception, which may contribute to impaired joint stability and an increased risk of falls. Open kinetic chain (OKC) and closed kinetic chain (CKC) exercises are commonly used to improve lower-limb function; however, their comparative effects on proprioception and functional stability in older adults remain insufficiently established. Therefore, this study aimed to compare the effects of OKC and CKC exercises on joint stability and proprioception in older adults.

Methods: A parallel-group randomised controlled trial was conducted among community-dwelling older adults aged ≥ 60 years. Eighty participants were randomly allocated equally to an OKC group ($n=40$) or a CKC group ($n=40$). The OKC group performed seated knee extensions, seated hamstring curls, straight leg raises, and hip adduction/abduction exercises, whereas the CKC group performed wall squats, step-ups, forward lunges, and weight-bearing calf raises. Both groups participated in supervised exercise sessions three times per week for 8 weeks. Proprioception was assessed using active knee joint position sense (JPS) error at target angles of 30° and 60° , while balance and functional stability were assessed using the Berg Balance Scale (BBS). Assessments were conducted at baseline and after completion of the intervention. Paired-samples t-tests were used for within-group comparisons, whereas independent-samples t-tests were used to compare changes between groups.

Results: Seventy-five participants completed the study, including 37 in the OKC group and 38 in the CKC group. Both groups demonstrated statistically significant improvements in JPS and BBS scores following the intervention. In the OKC group, JPS error decreased by 0.9° at 30° ($p=0.007$) and 1.0° at 60° ($p=0.005$), while BBS scores improved by 2.9 points ($p<0.001$). In the CKC group, JPS error decreased by 2.6° at 30° and 2.8° at 60° (both $p<0.001$), while BBS scores improved by 7.8 points ($p<0.001$). Between-group analysis demonstrated significantly greater improvements in the CKC group for JPS error at 30° (mean difference= 1.7° ,

$p < 0.001$), JPS error at 60° (mean difference = 1.8° , $p < 0.001$), and BBS score (mean difference = 4.9 points, $p < 0.001$).

Conclusion: Both OKC and CKC exercise programmes significantly improved proprioceptive accuracy and functional stability in older adults. However, CKC exercises produced significantly greater improvements in knee joint position sense and balance compared with OKC exercises. CKC exercise may therefore represent a more effective approach for enhancing functional stability and proprioception in older adults.

1. INTRODUCTION

Ageing is associated with progressive declines in muscle strength, neuromuscular control, balance, and sensory function, which can impair joint stability and proprioception. These age-related changes contribute to postural instability, gait disturbances, and an increased risk of falls, which are major causes of injury, disability, and loss of independence among older adults [1,2]. Proprioception provides essential information regarding joint position, movement, and force through sensory receptors located in muscles, tendons, ligaments, and joint capsules, thereby facilitating appropriate neuromuscular responses and dynamic joint stability [3].

With advancing age, reductions in sensory receptor sensitivity, nerve conduction, muscle mass, and rapid postural responses can compromise proprioceptive processing and neuromuscular control [4]. Impaired sensory integration and reduced muscular responses may consequently affect balance and functional mobility, increasing susceptibility to falls and other mobility-related complications [5]. Exercise is therefore considered an important non-pharmacological strategy for maintaining muscle function, balance, mobility, and neuromuscular performance in older adults [6]. In addition to maintaining physical activity, adequate nutrition and healthy dietary patterns are important for supporting overall health and well-being across the ageing process [7].

Open kinetic chain (OKC) and closed kinetic chain (CKC) exercises are commonly incorporated into therapeutic and rehabilitation programmes. In OKC exercises, the distal segment is freely mobile, allowing relatively isolated strengthening of individual muscle groups, such as during seated

knee extensions or hamstring curls. In contrast, CKC exercises involve a fixed or weight-bearing distal segment and simultaneous movement across multiple joints, as observed during squats, lunges, and step-ups. CKC exercises may provide greater sensory and neuromuscular stimulation because of weight-bearing, joint compression, co-contraction, and coordinated activation of multiple muscle groups [8].

The functional nature of CKC exercises may make them particularly relevant for older adults because their movement patterns resemble daily activities such as standing, walking, stair climbing, and transferring. Conversely, OKC exercises allow selective strengthening and may be useful when targeted muscle activation is required or when joint loading needs to be controlled [9]. However, it remains unclear whether the functional and weight-bearing characteristics of CKC exercises produce greater improvements in proprioception and functional stability than OKC exercises in older adults.

Although both exercise approaches have been investigated in orthopaedic and athletic populations, comparatively limited evidence is available regarding their effects on proprioception and joint stability specifically among older adults, particularly within the Pakistani context. Therefore, this study aimed to compare the effects of OKC and CKC exercises on knee joint position sense and functional balance in older adults. It was hypothesised that CKC exercises would produce greater improvements in proprioceptive accuracy and functional stability than OKC exercises [10].

2. CRITICAL SYNTHESIS OF EXISTING EVIDENCE

Existing literature demonstrates that joint stability is determined by a complex interaction between passive anatomical structures and active neuromuscular mechanisms. Early biomechanical research established the knee as a modified hinge joint involving coordinated rolling and gliding movements, while subsequent work highlighted the contribution of articular geometry and ligamentous structures to functional stability [6]. However, passive structures alone cannot adequately explain dynamic joint control. Research on mechanoreceptors within the anterior cruciate ligament and joint capsule established their importance in providing afferent information for proprioception and protective neuromuscular responses. Age-related reductions in proprioceptive acuity may therefore compromise these mechanisms and increase instability and fall risk in older adults [4]. Evidence has further demonstrated an association between impaired knee joint position sense and reduced functional performance, indicating that proprioceptive deficits have practical consequences for mobility and independence. Sensorimotor models have subsequently emphasised the interaction of sensory feedback, feed-forward control, and coordinated motor responses in maintaining joint stability, while research on neuromuscular fatigue has shown that delayed muscle responses to joint perturbations may further increase joint vulnerability [7].

The literature also supports neuromuscular and proprioceptive exercise as important components of rehabilitation and injury prevention. Landmark research demonstrated that structured neuromuscular training can substantially reduce injury risk, establishing the importance of targeted sensorimotor interventions [8]. Studies involving knee osteoarthritis and post-injury rehabilitation have similarly reported that impaired proprioception and neuromuscular control may contribute to functional limitations and joint instability, supporting the incorporation of proprioceptive training into rehabilitation programmes [9]. Long-term investigations

following anterior cruciate ligament reconstruction have further indicated that functional and sensorimotor deficits may persist despite surgical treatment, highlighting the need for sustained rehabilitation [10]. Comprehensive therapeutic exercise frameworks have consequently integrated joint mechanics, proprioception, and neuromuscular control into clinical practice, while contemporary evidence continues to support proprioceptive and neuromuscular training for individuals with chronic joint instability [11]. Collectively, these findings establish a strong theoretical basis for exercise-based improvement of proprioception and stability; however, much of the available evidence has focused on athletes, injured populations, or orthopaedic conditions rather than healthy older adults. Moreover, direct comparisons between open and closed kinetic chain exercises in elderly populations remain limited, highlighting the need for comparative research to determine which exercise approach provides greater improvements in proprioceptive accuracy and functional stability.

3. OBJECTIVES AND HYPOTHESES

The primary objective of this study was to compare the effects of open kinetic chain (OKC) and closed kinetic chain (CKC) exercises on joint stability and proprioception in older adults. Specifically, the study aimed to assess baseline joint stability and proprioception before intervention, evaluate the effects of 8-week OKC and CKC exercise programmes on these outcomes, and compare post-intervention changes between the two groups to determine which exercise approach produced superior functional outcomes. The null hypothesis (H_0) stated that there would be no statistically significant difference between OKC and CKC exercises in improving joint stability and proprioception, whereas the alternative hypothesis (H_1) stated that CKC exercises would produce significantly greater improvements in joint stability and proprioception than OKC exercises.

4. MATERIALS AND METHODS

A double-blinded, parallel-group randomised controlled trial (RCT) was conducted over six months, including participant recruitment, intervention, assessment, and data analysis. The study was conducted at the University Medical Center, University of Management and Technology (UMT), and Noor Vista Aesthetic and Wellness Center Lahore. The sample size was calculated using G*Power software, assuming a medium effect size (Cohen's $d=0.5$), 80% power, and a significance level of $\alpha=0.05$, resulting in approximately 34 participants per group; allowing for an anticipated 15% attrition rate, 80 participants (40 per group) were recruited. A two-stage sampling approach was adopted, whereby potential participants were recruited through senior citizen centres, community health campaigns, and hospital records, followed by computer-generated random allocation to the OKC or CKC exercise group. Eligible participants were aged ≥ 60 years, able to ambulate independently with or without a walking aid, able to understand and follow simple verbal instructions, had a Mini-Mental State Examination (MMSE) score ≥ 24 , and were medically stable and cleared by a physician to participate in moderate-intensity exercise [12]. Participants were excluded if they had sustained a lower-extremity or spinal fracture or undergone related surgery within the previous six months, had an unstable neurological disorder such as Parkinson's disease, uncontrolled epilepsy, or stroke with residual deficits, had uncontrolled cardiovascular disease including unstable angina or uncontrolled hypertension, had severe symptomatic knee or hip osteoarthritis limiting functional activity, had inflammatory joint disease such as rheumatoid arthritis during an acute flare-up, or had participated in a structured lower-limb strengthening programme during the previous three months [12].

INTERVENTION PROTOCOL

Following randomisation, participants were assigned to either an open kinetic chain (OKC) or closed kinetic chain (CKC) exercise group and

completed an 8-week supervised intervention. The OKC group performed seated knee extensions targeting the quadriceps, seated hamstring curls, straight leg raises, and side-lying hip adduction/abduction. The CKC group performed wall squats with ball support, step-ups onto a 15-cm platform, forward lunges with support, and weight-bearing calf raises. In both groups, exercises were performed for 3 sets of 10–12 repetitions at moderate intensity, corresponding to a rating of perceived exertion (RPE) of 12–14 on the Borg Scale, three times per week. Each participant therefore completed up to 24 supervised exercise sessions during the 8-week intervention period, with exercise intensity and technique monitored by the supervising physiotherapist.

OUTCOME MEASURES

Outcome assessments were conducted at baseline (week 0) and immediately after completion of the 8-week intervention (week 9) by an assessor who was blinded to group allocation. The primary outcome was proprioception, assessed using the active joint position sense (JPS) test of the dominant knee. Participants actively moved the knee to predetermined target angles of 30° and 60° of flexion and subsequently attempted to reproduce each target angle without visual feedback. The absolute difference between the target and reproduced angles was recorded in degrees, with a smaller angular error indicating better proprioceptive acuity. The secondary outcome was joint stability and functional balance, assessed using the Berg Balance Scale (BBS), a 14-item measure of static and dynamic balance. The BBS has a total score ranging from 0 to 56, with higher scores indicating better balance and lower risk of falls.

ETHICAL CONSIDERATIONS

The study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Institutional Review Board (IRB) of University Medical Center, University of Management and Technology (UMT), and Noor Vista Aesthetic and Wellness Center, Lahore before commencement of data

collection. All eligible participants received a detailed information sheet explaining the study purpose, procedures, potential risks, and benefits, and written informed consent was obtained before enrolment. Participant confidentiality was maintained by assigning unique identification codes and securely storing all data, which were accessible only to the research team. Participants were informed of their right to withdraw from the study at any stage without providing a reason or affecting their subsequent care. All exercise sessions were supervised by a qualified physiotherapist, and participants were screened for contraindications before intervention. Exercise technique, warm-up and cool-down procedures, and potential adverse events, including pain, dizziness, or falls, were monitored throughout the intervention.

DATA COLLECTION PROCEDURE

Following ethical approval, participants were recruited from the specified study settings and screened according to the predefined inclusion and exclusion criteria. Eligible participants who provided written informed consent underwent baseline assessment (T0) by a trained assessor blinded to group allocation. Demographic and clinical information, including age, gender, and relevant medical history, was recorded, followed by assessment of active knee joint position sense (JPS) and the Berg Balance Scale (BBS). Participants were then randomly allocated to the OKC or CKC group using sealed, opaque

envelopes containing a computer-generated randomisation sequence. Both groups subsequently completed their respective 8-week supervised exercise programmes, with attendance and adherence documented at each session. To maintain assessor blinding, the assessor responsible for outcome evaluation was not involved in exercise supervision. Within one week of completing the intervention, participants underwent post-intervention assessment (T1), during which the JPS and BBS were reassessed using the same procedures and by the same blinded assessor. All measurements were recorded on standardised data collection forms.

DATA ANALYSIS PROCEDURE

Data were entered and analysed using the Statistical Package for the Social Sciences (SPSS), version 25.0. Descriptive statistics were used to summarise baseline demographic and clinical characteristics, with continuous variables presented as mean $\pm$ standard deviation (SD) and categorical variables as frequencies and percentages. Within-group changes in JPS and BBS scores from baseline (T0) to post-intervention (T1) were analysed using paired-samples *t*-tests for the OKC and CKC groups separately. Between-group differences were assessed by comparing change scores ($\Delta = T1 - T0$) for JPS and BBS using independent-samples *t*-tests. Statistical significance was set at $p < 0.05$ for all analyses.

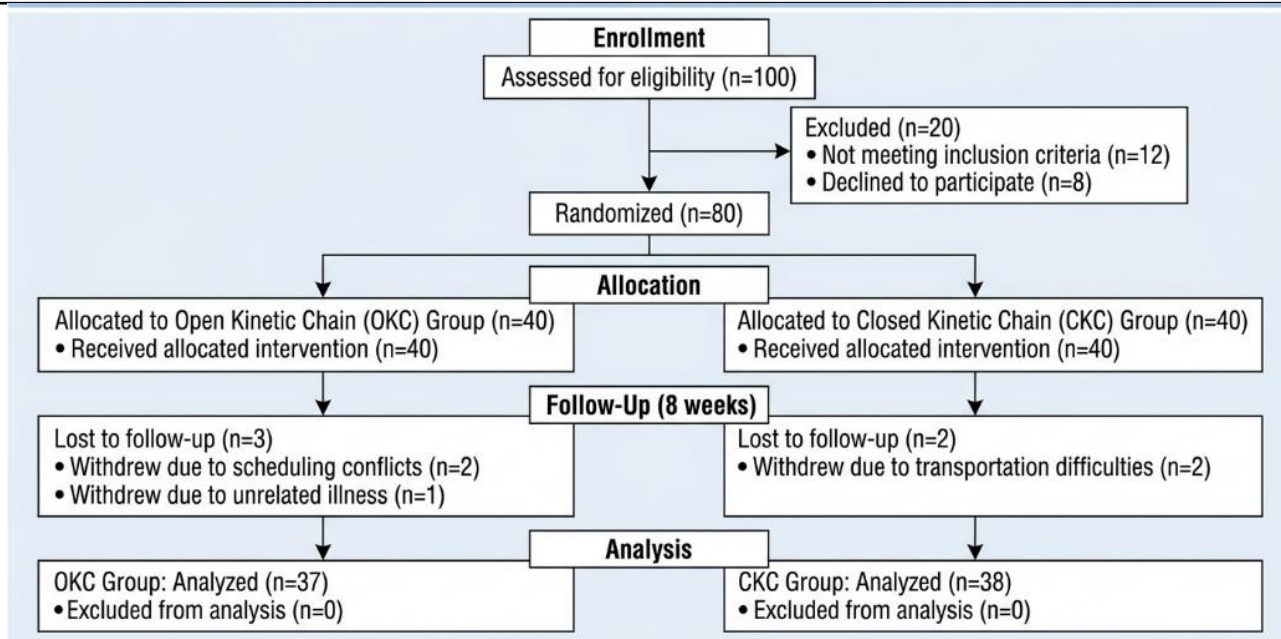


Figure 1. CONSORT Flow Diagram. Flow of participants through the recruitment, allocation, follow-up, and analysis phases of the 8-week randomized controlled trial comparing Open Kinetic Chain (OKC) and Closed Kinetic Chain (CKC) groups.

5. RESULTS

PARTICIPANT FLOW

A total of 100 individuals were assessed for eligibility, of whom 20 were excluded: 12 did not meet the inclusion criteria and 8 declined to participate. The remaining 80 participants were randomly allocated equally to the OKC group (n=40) and CKC group (n=40). During the 8-week intervention, three participants were lost to follow-up in the OKC group, including two who withdrew because of scheduling conflicts and one who withdrew due to an unrelated illness. In the CKC group, two participants withdrew because of transportation difficulties. Consequently, 37 participants in the OKC group and 38 in the CKC group completed the study and were included in the final analysis (total n=75).

BASELINE DEMOGRAPHIC AND CLINICAL CHARACTERISTICS

Table 1 presents the baseline demographic and clinical characteristics of participants in the OKC

and CKC groups. The mean age was 67.4 ± 5.2 years in the OKC group and 68.1 ± 5.6 years in the CKC group ($p=0.55$). Gender distribution was comparable between groups, with 16 males and 21 females in the OKC group and 15 males and 23 females in the CKC group ($p=0.71$). Mean BMI was 26.3 ± 3.1 kg/m² in the OKC group and 25.9 ± 2.8 kg/m² in the CKC group ($p=0.62$). Baseline JPS error at the 30° target was $6.8 \pm 2.1^\circ$ in the OKC group and $6.5 \pm 2.3^\circ$ in the CKC group ($p=0.58$), while at the 60° target it was $7.4 \pm 2.4^\circ$ and $7.1 \pm 2.2^\circ$, respectively ($p=0.61$). Baseline BBS scores were 44.2 ± 4.6 in the OKC group and 43.8 ± 4.9 in the CKC group ($p=0.70$). All baseline comparisons showed $p>0.05$, indicating no statistically significant differences between the groups before the intervention.

Table 1. Baseline Demographic and Clinical Characteristics of Participants

Variable	OKC Group (n=37)	CKC Group (n=38)	p-value
Age (years), mean $\pm$ SD	67.4 $\pm$ 5.2	68.1 $\pm$ 5.6	0.55
Gender, Male/Female	16/21	15/23	0.71
BMI (kg/m ²), mean $\pm$ SD	26.3 $\pm$ 3.1	25.9 $\pm$ 2.8	0.62
Baseline JPS error at 30° (°), mean $\pm$ SD	6.8 $\pm$ 2.1	6.5 $\pm$ 2.3	0.58
Baseline JPS error at 60° (°), mean $\pm$ SD	7.4 $\pm$ 2.4	7.1 $\pm$ 2.2	0.61
Baseline BBS score (/56), mean $\pm$ SD	44.2 $\pm$ 4.6	43.8 $\pm$ 4.9	0.70

TEST OF NORMALITY

The normality of the continuous outcome variables was assessed using the Shapiro–Wilk test at baseline and post-intervention in both groups. As the sample size was less than 50 participants per group, the Shapiro–Wilk test was considered appropriate, with Q–Q plots and skewness and kurtosis values also examined to support the assessment. As presented in Table 2, all outcome variables demonstrated a normal distribution, with Shapiro–Wilk *p*-values >0.05 across both

groups and assessment time points. For JPS error at the 30° target, *p*-values ranged from 0.201 to 0.462, while those for JPS error at the 60° target ranged from 0.176 to 0.510. BBS scores also showed no significant departure from normality, with *p*-values ranging from 0.279 to 0.634. Therefore, the assumption of normality was satisfied, supporting the use of parametric statistical tests, including paired-samples *t*-tests for within-group comparisons and independent-samples *t*-tests for between-group comparisons.

Table 2. Shapiro–Wilk Test of Normality

Variable	Group	Shapiro–Wilk (W)	df	p-value	Distribution
JPS error 30° (Baseline)	OKC	0.972	37	0.462	Normal
JPS error 30° (Baseline)	CKC	0.968	38	0.381	Normal
JPS error 30° (Post)	OKC	0.965	37	0.312	Normal
JPS error 30° (Post)	CKC	0.958	38	0.201	Normal
JPS error 60° (Baseline)	OKC	0.974	37	0.510	Normal
JPS error 60° (Baseline)	CKC	0.961	38	0.245	Normal
JPS error 60° (Post)	OKC	0.969	37	0.398	Normal
JPS error 60° (Post)	CKC	0.955	38	0.176	Normal
BBS score (Baseline)	OKC	0.978	37	0.634	Normal
BBS score (Baseline)	CKC	0.971	38	0.447	Normal
BBS score (Post)	OKC	0.966	37	0.328	Normal
BBS score (Post)	CKC	0.963	38	0.279	Normal

Note: JPS = joint position sense; BBS = Berg Balance Scale; OKC = open kinetic chain; CKC = closed kinetic chain. A *p*-value >0.05 indicates no statistically significant departure from normality.

WITHIN-GROUP CHANGES

Table 3 presents the within-group changes in knee joint position sense (JPS) error at 30° and 60° target angles from baseline to post-intervention. In the OKC group, JPS error at 30° decreased from 6.8 $\pm$ 2.1° to 5.9 $\pm$ 1.9°, representing a mean reduction of 0.9° (*t*=2.87, *p*=0.007). At the 60° target, JPS error decreased from 7.4 $\pm$ 2.4° to 6.4 $\pm$

2.0°, with a mean reduction of 1.0° (*t*=3.02, *p*=0.005). The CKC group demonstrated greater improvements, with JPS error at 30° decreasing from 6.5 $\pm$ 2.3° to 3.9 $\pm$ 1.6°, corresponding to a mean reduction of 2.6° (*t*=6.84, *p*<0.001). At 60°, JPS error decreased from 7.1 $\pm$ 2.2° to 4.3 $\pm$ 1.7°, representing a mean reduction of 2.8° (*t*=7.21, *p*<0.001). These findings indicate that both

exercise programmes significantly improved proprioceptive accuracy, with greater reductions in JPS error observed following CKC exercise.

Table 3. Within-Group Changes in Joint Position Sense Error

Group	Target Angle	Baseline Mean $\pm$ SD (°)	Post-intervention Mean $\pm$ SD (°)	Mean Change (°)	<i>t</i>	<i>p</i> -value
OKC	30°	6.8 $\pm$ 2.1	5.9 $\pm$ 1.9	-0.9	2.87	0.007
OKC	60°	7.4 $\pm$ 2.4	6.4 $\pm$ 2.0	-1.0	3.02	0.005
CKC	30°	6.5 $\pm$ 2.3	3.9 $\pm$ 1.6	-2.6	6.84	<0.001
CKC	60°	7.1 $\pm$ 2.2	4.3 $\pm$ 1.7	-2.8	7.21	<0.001

Table 4 presents the within-group changes in BBS scores. The OKC group demonstrated an increase in mean BBS score from 44.2 $\pm$ 4.6 at baseline to 47.1 $\pm$ 4.1 following the intervention, representing a mean improvement of 2.9 points ($t=4.15$, $p<0.001$). In the CKC group, the mean BBS score increased from 43.8 $\pm$ 4.9 to 51.6 $\pm$ 3.7,

corresponding to a mean improvement of 7.8 points ($t=9.63$, $p<0.001$). Thus, both groups demonstrated statistically significant improvements in functional balance, with the CKC group showing a substantially greater within-group improvement.

Table 4. Within-Group Changes in Berg Balance Scale Scores

Group	Baseline Mean $\pm$ SD	Post-intervention Mean $\pm$ SD	Mean Change	<i>t</i>	<i>p</i> value
OKC	44.2 $\pm$ 4.6	47.1 $\pm$ 4.1	+2.9	4.15	<0.001
CKC	43.8 $\pm$ 4.9	51.6 $\pm$ 3.7	+7.8	9.63	<0.001

Overall, both intervention groups showed statistically significant improvements in proprioceptive accuracy and functional balance following the 8-week exercise programme. However, the magnitude of improvement was consistently greater in the CKC group across all assessed outcomes.

BETWEEN-GROUP COMPARISON

Table 5 presents the comparison of change scores between the OKC and CKC groups. For JPS error at 30°, the OKC group demonstrated a mean reduction of 0.9 $\pm$ 1.9°, compared with a reduction of 2.6 $\pm$ 2.3° in the CKC group. The between-group mean difference was 1.7°, which was

statistically significant ($t=3.52$, $p<0.001$), indicating a greater improvement in proprioceptive accuracy following CKC exercise. Similarly, at the 60° target, JPS error decreased by 1.0 $\pm$ 2.1° in the OKC group and 2.8 $\pm$ 2.4° in the CKC group, yielding a significant between-group difference of 1.8° ($t=3.48$, $p<0.001$). For BBS scores, the OKC group improved by 2.9 $\pm$ 4.3 points, whereas the CKC group improved by 7.8 $\pm$ 5.0 points. The between-group mean difference was 4.9 points and was statistically significant ($t=4.61$, $p<0.001$). These findings demonstrate that CKC exercises produced significantly greater improvements in both knee proprioception and functional balance than OKC exercises.

Table 5. Between-Group Comparison of Change Scores

Outcome	OKC Δ Mean $\pm$ SD	CKC Δ Mean $\pm$ SD	Mean Difference	<i>t</i>	<i>p</i> -value
JPS error, 30°	-0.9 $\pm$ 1.9	-2.6 $\pm$ 2.3	1.7	3.52	<0.001
JPS error, 60°	-1.0 $\pm$ 2.1	-2.8 $\pm$ 2.4	1.8	3.48	<0.001
BBS score	+2.9 $\pm$ 4.3	+7.8 $\pm$ 5.0	4.9	4.61	<0.001

Overall, the between-group analysis demonstrated statistically significant differences in favour of CKC exercise for JPS error at both target angles and for BBS performance. The findings suggest that CKC exercise was more effective than OKC exercise in enhancing knee proprioceptive accuracy and functional balance among the older adults included in this study.

6. DISCUSSION

The present study compared the effects of open kinetic chain (OKC) and closed kinetic chain (CKC) exercises on proprioception and functional stability in older adults. Both interventions produced significant improvements in knee joint position sense (JPS) and Berg Balance Scale (BBS) scores after 8 weeks; however, the magnitude of improvement was significantly greater following CKC exercise. These findings support the proposed hypothesis that CKC exercise may provide greater benefits for proprioceptive accuracy and functional stability in older adults [13]. The two groups were comparable at baseline in terms of age, gender, BMI, JPS error, and BBS scores, indicating that the observed post-intervention differences were unlikely to be explained by substantial baseline imbalance and supporting the effectiveness of random allocation [14].

The OKC group demonstrated significant reductions in JPS error at both 30° and 60° target angles, indicating improved proprioceptive accuracy [15]. This improvement may reflect enhanced strength, selective muscle activation, and neuromuscular control resulting from repeated isolated knee and hip exercises. Targeted activation of the quadriceps and hamstrings may improve sensory feedback from muscle and tendon receptors and facilitate more accurate reproduction of joint position [16]. Thus, although OKC exercises involve a freely moving

distal segment, repeated controlled movement can still provide sufficient sensory input to support proprioceptive adaptation and remains valuable when selective muscle strengthening is required [17].

Greater improvements were observed in the CKC group, with JPS error decreasing by 2.6° at 30° and 2.8° at 60°. This superior effect may be attributed to the weight-bearing and multi-joint characteristics of CKC movements, which require simultaneous activation of several muscle groups, agonist-antagonist co-contraction, joint loading, and continuous postural adjustment [18,19]. Exercises such as wall squats, step-ups, lunges, and calf raises require coordinated control of the hip, knee, and ankle while maintaining equilibrium, potentially providing greater proprioceptive and sensorimotor stimulation than isolated movements [20]. Previous research has similarly suggested beneficial effects of kinetic-chain and neuromuscular exercise on postural control, strength, and functional performance in older adults.

Both groups also demonstrated significant improvements in BBS scores, although the CKC group showed a considerably larger improvement (7.8 vs. 2.9 points) [21]. This difference may be explained by the greater task specificity of CKC exercises, as squatting, stepping, lunging, and weight transfer closely resemble activities assessed by the BBS, including standing, transferring, reaching, turning, and maintaining postural control [22]. Repeated exposure to weight-bearing functional movements may therefore enhance lower-limb coordination, postural reactions, and confidence during movement, which are particularly important for reducing functional limitations and fall risk in older adults [23].

The between-group analysis further demonstrated significantly greater improvements in the CKC group for JPS error at both 30° and 60° and for

BBS scores, with mean differences of 1.7°, 1.8°, and 4.9 points, respectively [24]. These findings suggest that although both exercise approaches are effective, CKC exercises may provide a stronger stimulus for proprioceptive and functional adaptations. The greater effect may result from the combined influence of weight-bearing, joint compression, multi-joint coordination, muscle co-contraction, and continuous postural adjustments inherent to CKC activities [25]. Previous studies comparing kinetic-chain approaches have also reported differences in postural control and functional performance, supporting the importance of exercise selection when targeting sensorimotor outcomes [26].

Clinically, these findings suggest that OKC and CKC exercises should not necessarily be considered competing approaches. OKC exercises may be useful during initial rehabilitation or when isolated muscle strengthening and controlled loading are required, whereas CKC exercises can be progressively introduced as strength, balance, and exercise tolerance improve [27]. A combination of selective strengthening and progressive functional weight-bearing exercises may therefore provide a comprehensive rehabilitation strategy for older adults. This approach is consistent with evidence indicating that age-related sensory and neuromuscular changes contribute to impaired postural stability and that proprioceptive and neuromuscular training can improve balance and sensorimotor performance [28]. Beyond exercise-based interventions, lifestyle-related factors, including dietary patterns and the timing of nutrient intake, may also influence metabolic health and physical function in older adults. Therefore, exercise-based rehabilitation may be most effective when integrated with broader lifestyle and health-promotion strategies.[29]

The present findings are also broadly consistent with previous kinetic-chain research reporting improvements in postural control and muscular performance among older populations [30]. Although evidence from knee osteoarthritis and other orthopaedic populations cannot be directly generalised to community-dwelling older adults, it

provides additional support for the functional benefits of weight-bearing and multi-joint exercise.[31] Importantly, the present study extends this evidence by directly comparing OKC and CKC exercise and demonstrating greater improvements in both proprioceptive accuracy and functional balance following CKC training. [32]The significant between-group differences support rejection of the null hypothesis and provide evidence in favour of the alternative hypothesis that CKC exercise produces greater improvements in proprioception and functional stability in older adults [33].

7. CONCLUSION

Both OKC and CKC exercise programmes significantly improved proprioceptive accuracy and functional balance in older adults following 8 weeks of training. However, CKC exercises produced significantly greater improvements in knee JPS at both 30° and 60° target angles and in BBS scores compared with OKC exercises. The superior effects of CKC exercise may be associated with its weight-bearing, multi-joint, co-contraction, and continuous postural-control demands. Therefore, CKC exercises may be particularly beneficial for improving proprioception and functional stability in older adults, while OKC exercises remain useful for targeted muscle strengthening.

8. LIMITATIONS

This study has several limitations. First, the final sample comprised 75 participants, which may limit the generalisability of the findings to the broader older adult population. Second, the intervention lasted only 8 weeks, preventing assessment of the long-term sustainability of the observed improvements. Third, participants were recruited from specific clinical and community settings, which may limit applicability to older adults with different health conditions or functional abilities. Proprioception was assessed only at 30° and 60° of knee flexion, which may not represent proprioceptive performance across the entire range of motion. In addition, the BBS primarily evaluates functional balance and

postural control rather than joint stability directly. Finally, complete blinding of participants and therapists was not possible because the nature of the exercise interventions was evident.

9. RECOMMENDATIONS

Future research should include larger and more diverse samples to improve the generalisability of findings and should incorporate longer intervention and follow-up periods to determine the persistence of improvements. Additional objective measures of proprioception, postural stability, muscle strength, and functional mobility should also be considered. Further randomised controlled trials should investigate combined OKC and CKC programmes and compare different exercise intensities, frequencies, and progression strategies. Research should also examine these interventions among older adults with varying levels of physical function and common age-related musculoskeletal conditions to establish their broader clinical applicability.

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