(ISSN: 0973-7049(P))

The Bioscan AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES 21(2): S.I (2), 21896-21907, 2026 www.thebioscan.com

Comparative Effects of Strength and Balance Training on Fall-Risk Indicators in Older Adults with Knee Osteoarthritis: A Randomized Trial With 9-Month Follow-Up

[1]Ashwani Kumar, [2]Dr. Jafar Khan, [3]Dr. Deepak Lohar, [4]Dr. K. M. Annamali, [5]Dr Reshma Khurana , [6]Dr. Renuka Pal, [7]Dr. Vaishnavi Jayant Kania, [8]Dr. Abhishek Arora, [9]Dr Hasnen Sheikh, [10]Khushi Vishwakarma

[*1]M.P.Th. scholar, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan

[2]Dean & HOD, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan

[3]Professor, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan

[4]Consultant Senior Physiotherapist & Director Physio Alliance Apollo Hospital, Ahmedabad, Gujarat, India

[5]Principal, Index Department of Physiotherapy and Paramedical Sciences, Malwanchal university, Indore

[6]Professor, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan

[7]Assistant Professor, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan

[8]Assistant Professor, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan

[9]Assistant Professor, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan

[10]M.P.Th. scholar, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan

Corresponding author: Ashwani Kumar | Email: drashwanikumarphysio@gmail.com

DOI:https://doi.org/10.63001/tbs.2026.v21.i02.S.I(2).pp21896-21907

KEYWORDS

balance training; falls; knee osteoarthritis; older adults; strength training; rehabilitation

Article Info

Received: 27.05.2026

Accepted: 15.06.2026

Published: 25.06.2026

Abstract

Background: Knee osteoarthritis is associated with pain, lower-limb weakness, impaired proprioception, altered gait, and increased fall risk. Strength and balance exercises address different mechanisms, but direct comparative evidence with longer follow-up remains limited.

Objective: To compare the effects of progressive lower-limb strength training and progressive balance training on functional mobility, postural control, concern about falling, and composite fall risk in older adults with knee osteoarthritis.

Methods: This prospective randomized comparative trial included 60 adults aged 50-75 years with clinically and radiologically diagnosed knee osteoarthritis. Participants were allocated equally to strength training (n=30) or balance training (n=30). Both groups completed 24 supervised sessions over 6 weeks. Outcomes were assessed at baseline, 3 months, and 9 months using the Timed Up and Go test (TUG), Berg Balance Scale (BBS), Falls Efficacy Scale-International (FES-I), and Falls Risk Assessment Tool (FRAT). Between-group mean differences, 95% confidence intervals (CIs), and Hedges g were calculated.

Results: Baseline outcome values did not differ significantly. At 9 months, balance training was superior for TUG (10.36+/-1.67 vs 13.19+/-1.29 s; mean difference [MD] -2.83 s, 95% CI -3.60 to -2.06; p<0.001), BBS (47.60+/-3.32 vs 44.40+/-2.28; MD 3.20, 95% CI 1.72 to 4.68; p<0.001), FES-I (22.20+/-4.74 vs 25.67+/-3.12; MD -3.47, 95% CI -5.55 to -1.39; p=0.002), and FRAT (2.93+/-1.23 vs 3.87+/-0.90; MD -0.94, 95% CI -1.50 to -0.38; p=0.001). Hedges g ranged from 0.85 to 1.87 in magnitude.

Conclusion: Both interventions improved fall-risk indicators, but progressive balance training produced greater and more sustained benefits. Rehabilitation for older adults with knee osteoarthritis should include challenging static and dynamic balance activities, supported by lower-limb strengthening.

1. Introduction

Knee osteoarthritis (OA) is a chronic disorder of the whole synovial joint and a major cause of pain, activity limitation, and reduced quality of life in older adults [1]. Its consequences extend beyond local joint degeneration. Pain, stiffness, quadriceps inhibition, reduced range of motion, and avoidance of weight-bearing activity can alter transfer performance and gait. Older adults with symptomatic knee OA commonly walk more slowly, use shorter steps, and spend more time in double support, while age-related decline in sensory integration and reaction speed further reduces the ability to recover from instability.

Balance impairment is consistently observed in symptomatic knee OA [2]. A systematic review identified impaired balance, muscle weakness, comorbidity burden, and a greater number of symptomatic joints as relevant fall-risk factors [3]. Knee instability and reduced lower-limb strength are also associated with falls in people who report that the knee gives way [4]. These findings support a rehabilitation approach that targets both the force-generating capacity of the lower limb and the sensory-motor control required to keep the centre of mass within a safe base of support.

Strength training is widely used in knee OA because stronger quadriceps, hamstrings, hip muscles, and plantar flexors can improve joint support, transfers, stair negotiation, and gait. However, strength gains alone may not restore anticipatory postural adjustments, turning control, rapid stepping, or confidence during challenging mobility. Balance training directly exposes patients to reduced bases of support, weight transfer, directional stepping, obstacle negotiation, and sensory challenges. Reviews suggest that physical therapies with a meaningful balance component can improve balance and fall-risk measures in knee OA [5], yet balance training remains inconsistently used in routine physiotherapy [6].

Exercise-based fall-prevention evidence in older adults generally favours programmes that challenge postural control [7]. In knee OA, however, many trials combine strengthening, balance, aerobic exercise, and conventional physiotherapy, making it difficult to determine which component contributes most to improvement. Direct comparisons are particularly important when treatment time is limited and clinicians must prioritize a principal exercise strategy.

The present study compared an isolated progressive strength programme with a progressive balance programme delivered at the same frequency and duration. The objective was to compare effects on functional mobility, clinical balance, concern about falling, and composite fall risk at baseline, 3 months, and 9 months. It was hypothesized that balance training would produce greater long-term improvement than strength training.

2. Methods

2.1 Study design and setting

A prospective, two-group randomized comparative interventional design was used. The study was conducted in the Physiotherapy Outpatient Department of Pacific Medical College and Hospital, Udaipur, Rajasthan, India. Participants were allocated in a 1:1 ratio to a strength training group (STG) or balance training group (BTG). The supervised intervention lasted 6 weeks, and outcomes were assessed at baseline, 3 months, and 9 months.

The manuscript follows the structure of a parallel-group clinical trial report. Because the available thesis records did not document screening and exclusion counts before randomization, only randomized and analyzed participant counts are reported.

2.2 Participants

Adults aged 50-75 years with clinically and radiologically diagnosed knee OA were recruited from physiotherapy and orthopaedic referrals. Participants were required to be medically stable, able to ambulate independently with or without a stick or walker, willing to attend treatment, and able to provide written informed consent.

Exclusion criteria were knee surgery or fracture during the preceding 6 months; a severe neurological, cognitive, or vestibular disorder affecting balance; uncontrolled cardiovascular, metabolic, or systemic illness; another major lower-limb or spinal condition that substantially affected gait; or inability to attend sessions and follow-up assessments.

A feasibility sample of 60 participants was adopted from comparable intervention studies and the recruitment capacity of the centre. Thirty participants were analyzed in each group at each reported assessment.

2.3 Randomization and allocation

After baseline assessment, eligible participants were assigned to STG or BTG through a simple random allocation procedure. Allocation was documented before treatment began. Participants and treating therapists could not be blinded because the exercise content was visible. The same standardized instructions, equipment placement, and scoring procedures were used at each assessment. Allocation concealment and assessor blinding were not documented in the thesis record.

2.4 Interventions

Both groups received 24 supervised sessions, four sessions per week for 6 consecutive weeks. Sessions lasted approximately 40-50 minutes and included a 5-7 minute warm-up, the assigned exercise component, and a 5-minute cool-down. Progression was individualized according to pain, alignment, movement quality, fatigue, and safety. Attendance and adverse responses were recorded. Participants were educated about safe mobility, footwear, assistive-device use, and home fall-prevention precautions.

Table 1. Summary of the intervention protocols

Phase	Strength training group	Balance training group	Dose/progression
Warm-up	Comfortable walking; active knee and ankle movements	Comfortable walking; multidirectional weight shifting	5-7 min

Weeks 1-2	Quadriceps sets, straight-leg raise, seated knee extension, heel raises	Feet-together and semi-tandem stance; supported tandem and single-leg stance; weight shifting	Strength: 2 sets x 10 repetitions. Balance: 3 trials x 20-30 s.
Weeks 3-4	Mini-squats, sit-to-stand, step-ups, resisted knee extension, hip abduction and extension	Tandem walking, lateral and backward stepping, multidirectional reaching, step initiation, controlled turns	Resistance, task distance, direction changes, and support adjusted to performance.
Weeks 5-6	Progressive squats, higher step-ups, resisted sit-to-stand, calf raises	Obstacle negotiation, figure-of-eight walking, 90-degree and 180-degree turns, compliant-surface stance, simple dual-task walking	Strength: 3 sets x 10-15 repetitions. Balance: increased duration, speed, complexity, and reduced support.
Cool-down	Lower-limb stretching and breathing	Slow walking, relaxed breathing, gentle lower-limb movements	Approximately 5 min

All exercises were supervised by a physiotherapist. Support surfaces, parallel bars, a chair, or a gait belt were used when required for safety.

2.5 Outcome measures

Functional mobility was assessed with the Timed Up and Go test (TUG). Participants rose from a standard chair, walked 3 m, turned, returned, and sat down; a lower time indicated better mobility [12].

Functional balance was assessed with the 14-item Berg Balance Scale (BBS), scored from 0 to 56; a higher score indicated better balance [13].

Concern about falling was assessed with the 16-item Falls Efficacy Scale-International (FES-I). Each item is scored from 1 to 4, with a higher total score indicating greater concern about falling [14].

Composite fall risk was assessed with the Falls Risk Assessment Tool (FRAT), which incorporates previous falls, medication and medical factors, mobility, cognition, behaviour, and environmental hazards; a higher score indicates greater risk [15].

2.6 Data collection and statistical analysis

Demographic and clinical information was collected using a structured proforma. Continuous data were summarized as mean and standard deviation (SD), and categorical data as frequency and percentage. Between-group comparisons at each time point were calculated using Welch independent-samples t tests because the group SDs were not assumed to be

(ISSN: 0973-7049(P))

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equal. Statistical significance was set at $p<0.05$.

To improve interpretability, the balance-minus-strength mean difference (MD), 95% confidence interval (CI), and Hedges g were calculated from the reported group means, SDs, and sample sizes. For TUG, FES-I, and FRAT, negative values favoured balance training; for BBS, positive values favoured balance training. Baseline-to-9-month changes were also summarized as absolute and percentage changes. No imputation was required for the reported outcome tables.

2.7 Ethical considerations

The Institutional Ethics Committee of Pacific Medical College and Hospital, Udaipur approved the protocol (PMU/IEC/MPT/2025/05) at its meeting on 3 October 2025; the approval letter was issued on 7 November 2025. All participants received study information in understandable language and provided written informed consent. Participation was voluntary, confidentiality was maintained, and supervised safety precautions were used throughout treatment.

3. Results

3.1 Participant and baseline characteristics

The reported analytical sample included 60 participants, with 30 in STG and 30 in BTG at baseline, 3 months, and 9 months. Mean age was 63.40+/-4.30 years in STG and 64.60+/-4.67 years in BTG. Mean body mass index was 29.33+/-1.07 and 29.56+/-1.72 kg/m2, respectively. Each group comprised 18 women (60%) and 12 men (40%).

Age, body mass index, sex distribution, and baseline outcome scores were similar. Descriptive differences were present in fall history and fear-of-falling categories: BTG contained more participants with three or four previous falls and more participants classified with severe fear of falling. Despite this less favourable clinical profile, baseline FES-I and FRAT means did not differ significantly.

Table 2. Baseline demographic and clinical characteristics

Characteristic	Strength training (n=30)	Balance training (n=30)
Age, years, mean+/-SD	63.40+/-4.30	64.60+/-4.67
BMI, kg/m2, mean+/-SD	29.33+/-1.07	29.56+/-1.72
Women, n (%)	18 (60.0)	18 (60.0)
Bilateral knee involvement, n (%)	16 (53.3)	18 (60.0)
Moderate pain, n (%)	20 (66.7)	18 (60.0)
Severe pain, n (%)	10 (33.3)	12 (40.0)
Used stick or walker, n (%)	16 (53.3)	18 (60.0)

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One previous fall, n (%)	14 (46.7)	6 (20.0)
Two previous falls, n (%)	12 (40.0)	6 (20.0)
Three or four previous falls, n (%)	4 (13.3)	18 (60.0)
Severe fear of falling, n (%)	10 (33.3)	24 (80.0)

BMI, body mass index; SD, standard deviation. Categorical characteristics are descriptive; no baseline hypothesis tests were reported for these variables.

3.2 Functional mobility

TUG time declined in both groups. At 3 months, the BTG mean was 0.90 s lower than the STG mean (14.18+/-0.94 vs 15.08+/-1.07 s; p=0.001). At 9 months, the difference widened to 2.83 s (95% CI -3.60 to -2.06; p<0.001; Hedges g=-1.87). From baseline to 9 months, STG improved by 4.78 s (26.6%), whereas BTG improved by 7.86 s (43.1%).

3.3 Functional balance

BBS scores increased in both groups. BTG was higher than STG at 3 months (43.60+/-2.28 vs 39.77+/-1.77; p<0.001) and 9 months (47.60+/-3.32 vs 44.40+/-2.28). The 9-month MD was 3.20 points (95% CI 1.72 to 4.68; p<0.001; Hedges g=1.11). The baseline-to-9-month gain was 8.20 points in STG and 12.20 points in BTG.

3.4 Concern about falling and composite fall risk

FES-I scores decreased in both groups. At 3 months, BTG had a 2.33-point lower mean than STG (p=0.009). At 9 months, the MD was -3.47 points (95% CI -5.55 to -1.39; p=0.002; Hedges g=-0.85). The total reduction was 10.66 points (29.3%) in STG and 15.80 points (41.6%) in BTG.

FRAT scores also decreased. The between-group difference was not statistically significant at 3 months (MD -0.47, p=0.089) but was significant at 9 months (MD -0.94, 95% CI -1.50 to -0.38; p=0.001; Hedges g=-0.86). The baseline-to-9-month reduction was 48.6% in STG and 61.4% in BTG.

Table 3. Outcome scores at baseline, 3 months, and 9 months

Outcome/time	Strength training, mean+/-SD	Balance training, mean+/-SD	Mean difference (BTG-STG)	p value
TUG baseline, s	17.97+/-0.82	18.22+/-0.65	0.25	0.196
TUG 3 months, s	15.08+/-1.07	14.18+/-0.94	-0.90	0.001
TUG 9 months, s	13.19+/-1.29	10.36+/-1.67	-2.83	<0.001

BBS baseline	36.20+/-2.35	35.40+/-2.04	-0.80	0.165
BBS 3 months	39.77+/-1.77	43.60+/-2.28	3.83	<0.001
BBS 9 months	44.40+/-2.28	47.60+/-3.32	3.20	<0.001
FES-I baseline	36.33+/-3.81	38.00+/-3.44	1.67	0.080
FES-I 3 months	30.53+/-2.67	28.20+/-3.83	-2.33	0.009
FES-I 9 months	25.67+/-3.12	22.20+/-4.74	-3.47	0.002
FRAT baseline	7.53+/-0.51	7.60+/-0.50	0.07	0.593
FRAT 3 months	5.47+/-0.73	5.00+/-1.29	-0.47	0.089
FRAT 9 months	3.87+/-0.90	2.93+/-1.23	-0.94	0.001

BBS, Berg Balance Scale; BTG, balance training group; FES-I, Falls Efficacy Scale-International; FRAT, Falls Risk Assessment Tool; SD, standard deviation; STG, strength training group; TUG, Timed Up and Go. p values were calculated with Welch independent-samples t tests from reported summary statistics.

Table 4. Between-group effect estimates at 9 months

Outcome	Mean difference (BTG-STG)	95% CI	p value	Hedges g
TUG, s	-2.83	-3.60 to -2.06	<0.001	-1.87
BBS, points	3.20	1.72 to 4.68	<0.001	1.11
FES-I, points	-3.47	-5.55 to -1.39	0.002	-0.85
FRAT, points	-0.94	-1.50 to -0.38	0.001	-0.86

Negative differences favour BTG for TUG, FES-I, and FRAT; positive differences favour BTG for BBS. CI, confidence interval.

4. Discussion

4.1 Principal findings

Both exercise approaches improved all four fall-risk indicators, but balance training produced larger gains and the advantage generally increased over time. By 9 months, balance training was superior for functional mobility, clinical balance, concern about falling, and composite fall risk. The magnitudes of the standardized effects were moderate-to-large for FES-I and FRAT and large for BBS and TUG.

The balance group began with a less favourable descriptive profile for previous falls and severe fear of falling. Nevertheless, its standardized baseline outcome scores were not significantly different and its follow-up scores were consistently better. This pattern reduces the likelihood that the observed direction of benefit was explained by an initially lower-risk balance group.

4.2 Functional mobility and balance

Strength training can improve transfer performance by increasing quadriceps and hip force, reducing the likelihood of knee collapse, and increasing the muscular reserve available for stepping. Exercise is an established component of knee OA management [8], and systematic review evidence supports progressive strength training for pain and physical function [9]. The meaningful improvement in STG is therefore clinically plausible and reinforces the importance of strengthening in rehabilitation.

The larger TUG and BBS improvements after balance training may be explained by task specificity. TUG requires standing, acceleration, turning, deceleration, and controlled sitting, while BBS includes narrow-base standing, reaching, stepping, turning, and single-leg tasks. The balance protocol repeatedly practiced these components through weight shifting, tandem tasks, directional stepping, obstacle negotiation, compliant surfaces, and dual-task walking. A pilot randomized trial similarly reported improved pain and physical function after dynamic balance training in knee OA [10]. Systematic review evidence also indicates that balance exercises improve postural stability and functional outcomes [11].

The present 9-month TUG difference of 2.83 s and BBS difference of 3.20 points were accompanied by large standardized effects. Although clinical thresholds vary across populations, the direction and magnitude indicate that the difference was not limited to statistical significance. The growing separation between groups from 3 to 9 months suggests that learned balance strategies may have transferred to everyday mobility or encouraged continued activity.

4.3 Concern about falling

Fear of falling can promote cautious gait, activity restriction, deconditioning, and excessive attentional focus on movement. Balance training provides repeated successful exposure to tasks that patients may otherwise avoid. Under supervision, participants practiced turning, stepping, narrowing the base of support, and negotiating obstacles. Mastery of these tasks can improve perceived control as well as physical performance.

FES-I decreased in both groups, but the reduction was greater after balance training even though BTG contained more participants with severe fear at baseline. The result supports a combined physical and behavioural mechanism: repeated successful practice may reduce threat perception, increase confidence, and encourage further mobility. This is clinically important because confidence may influence adherence and community participation even when pain remains present.

4.4 Composite fall risk and relation to existing evidence

The FRAT difference was not significant at 3 months but became significant at 9 months. A composite score may require broader changes in mobility, confidence, behaviour, and instability before clear separation appears. The delayed benefit therefore fits the multidimensional nature of fall risk.

The findings align with evidence that challenging postural-control exercise is among the most effective exercise strategies for preventing falls in community-dwelling older adults [7]. They also extend knee OA evidence by directly comparing two active programmes with equal contact time. Anderson et al. found that a substantial proportion of adults with symptomatic knee OA were at high fall risk, yet balance training was not consistently included in physiotherapy [6]. The present results provide a practical rationale for correcting that underuse.

Clinical trials and reviews in knee OA have reported beneficial effects of balance-focused exercise on function [10,11,17,18], while a meta-analysis found significant improvement in TUG after balance training [19]. The current study adds longer-term comparative data and demonstrates that balance-specific gains can remain evident at 9 months.

4.5 Clinical implications

Physiotherapists treating older adults with knee OA should assess fall history, fear of falling, gait characteristics, assistive-device use, turning ability, and postural control rather than focusing only on pain and knee range of motion. When fall-risk reduction is a principal goal, balance activities should be progressive and sufficiently challenging to stimulate adaptation while remaining safe.

A clinically practical programme can begin with supported feet-together, semi-tandem, and weight-shifting tasks; advance to tandem walking, multidirectional stepping, turning, and reaching; and progress to obstacles, compliant surfaces, dual-task walking, and reduced upper-limb support. Lower-limb strengthening should be retained because effective balance reactions require adequate force and power. In routine practice, an integrated programme is therefore preferable, with the emphasis adjusted to the patient's dominant impairment.

4.6 Strengths and limitations

Strengths included an active comparison group, matched treatment frequency and session duration, standardized outcome measures spanning physical and psychological domains, and follow-up to 9 months. Reporting effect estimates and confidence intervals also improves interpretation beyond p values alone.

Several limitations should be considered. The study was conducted at one centre with a moderate feasibility sample and no formal a priori power calculation. Details of allocation concealment and assessor blinding were not available. Participant and therapist blinding was impossible. The analysis did not include a group-by-time mixed model because participant-level longitudinal data were not available in the thesis record used for manuscript preparation. Baseline clinical imbalances in fall history and fear categories may have influenced response. Adherence to home practice after the supervised phase was not fully controlled. Actual prospective fall incidence was not reported; therefore, conclusions apply to validated fall-risk indicators rather than confirmed reduction in fall events. Pain severity and radiographic grade were not evaluated as effect modifiers.

5. Conclusion

Progressive strength and balance training both improved fall-risk indicators in older adults with knee OA. Balance training produced greater and more sustained improvement in mobility, functional balance, concern about falling, and composite fall risk through 9 months. Rehabilitation should prioritize progressive, task-specific balance challenge when fall-risk reduction is the main goal, while preserving lower-limb strengthening as an essential complementary component. Larger multicentre trials should include prospective fall counts, concealed allocation, blinded outcome assessment, adherence monitoring, and mixed-model analysis of repeated measures.

Declarations

Ethics approval and consent to participate:

Approved by the Institutional Ethics Committee of Pacific Medical College and Hospital, Udaipur (PMU/IEC/MPT/2025/05; committee approval 3 October 2025; approval letter 7 November 2025). Written informed consent was obtained from all participants.

Consent for publication

Not applicable.

Availability of data and materials

The summary data supporting the findings are presented in the manuscript. Access to participant-level data is subject to institutional and ethical approval and may be requested from the corresponding author.

Funding

No external research funding was reported in the thesis.

Competing interests

The authors declare that they have no competing interests.

Author contributions

AK: conceptualization, investigation, data collection, formal analysis, and drafting of the manuscript. JK: supervision, methodology oversight, interpretation of findings, and critical revision of the manuscript. Both authors approved the final manuscript.

Acknowledgements

The authors acknowledge the Department of Physiotherapy, Pacific Medical College and Hospital, Udaipur, and the participants who contributed to the study.

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