Comparative Analysis of Proprioceptive Exercises versus Conventional Physical Therapy Interventions on Balance among patients with Knee Osteoarthritis

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ABSTRACT

Background: Knee osteoarthritis (KOA) has often been linked to the deficiency of proprioception and balance impairment, which results in a functional limitation and the risk of falls. Proprioceptive exercise can possibly have better neuromuscular effects than conventional Physical Therapy **Objective:** This research aimed to compare the effects of proprioceptive exercises and traditional Physical Therapy on the balance among patients with KOA. **Methods:** It was a randomized controlled trial involving 40 subjects who had KOA (KL grades 23). The participants were randomly distributed in Proprioceptive Exercise Group (PEG; n=20), and Control Group (CG; n=20). These two groups were subjected to pulsed ultrasound treatment and then was subjected to structured proprioceptive exercises (PEG) or conventional Physical Therapy (CG) in a period of 10 weeks. The Berg balance Scale (BBS) was used to measure balance at Baseline, Week 4, Week 8 and Week 10. Repeated-measures ANOVA was carried out, as well as post-hoc tests. **Results:** Both groups had a similar baseline score, but the PEG showed significantly better improvements in balance at all follow up periods. Week 4 (PEG), Week 8 (PEG) and Week 10 (PEG) all showed a favorable mean difference (PEG). The significance of the overall between-group effect was high (-0.56; 95% CI: -0.72 -0.40; p<0.001), and the interaction effect is large (F(1,38)=132.98; η²=0.823). The balance trend graph depicted sharper trend of improvement in PEG. **Conclusion:** Proprioceptive training resulted in much larger enhancement of balance in comparison to standard Physical Therapy, which is why they should be incorporated into the rehabilitation of KOA.

Keywords
knee osteoarthritis, proprioception, balance training, Berg Balance Scale, physical therapy, randomized controlled trial.

INTRODUCTION

Knee osteoarthritis (KOA) is a degenerative, chronic, and highly prevalent joint condition characterized by the progressive loss of hyaline cartilage, subchondral bone remodeling, and synovial inflammation. These structural alterations, alongside significant neuromuscular impairments, culminate in persistent pain, joint stiffness, and profound functional limitations (1-5). Given the global burden of this condition, international clinical guidelines consistently advocate for therapeutic exercise as the gold standard of conservative management (5-7). However, an increasingly recognized yet historically neglected aspect of KOA pathology is proprioceptive dysfunction. This impairment arises from degenerative changes in joint mechanoreceptors, localized inflammation, and persistent joint effusion, which collectively disrupt the afferent feedback loops essential for neuromuscular control (8,9).

Proprioceptive deficits in KOA are strongly associated with compromised balance, diminished postural stability, and impaired gait control. These sensory-motor impairments are particularly detrimental in older adults, significantly elevating the risk of falls. Emerging evidence suggests that these deficits are inherent characteristics of the disease process itself, rather than a secondary consequence of pain-avoidance behaviors (10-14). In contrast, classical physical therapy has traditionally focused on muscle strengthening, stretching, and range-of-motion activities. While effective for symptomatic relief and force production, these traditional modalities often provide suboptimal benefits for neurosensory deficits and the balance impairments intrinsically linked to KOA pathology (15-17).

Proprioceptive training represents a paradigm shift by focusing on sensorimotor re-education through balance-board practice, closed kinetic chain exercises, and perturbation training. A growing body of evidence, including systematic reviews and meta-analyses, indicates that targeting joint position sense can significantly improve muscle-related functions, dynamic stability, and gait parameters in individuals with KOA (18-27). Comparative studies have even suggested that proprioceptive training, when integrated with Maitland mobilization or other neuromuscular methods, provides superior functional outcomes compared to isolated ultrasound therapy or standard open-chain strengthening (24,18,20).

Despite this promising evidence, clinical uncertainty persists due to substantial heterogeneity in exercise dosages, intervention durations, and the specific assessment tools utilized across studies. This variability complicates definitive conclusions regarding the comparative effectiveness of proprioceptive versus conventional physical therapy, particularly concerning balance outcomes. Given that a significant portion of disability and decreased quality of life in KOA patients is attributed to balance impairment and fall risk, elucidating these disparities is imperative for evidence-based clinical decision-making (28,29). This research provides a comparative analysis of proprioceptive and conventional physical therapy

interventions on balance in KOA patients, addressing a critical knowledge gap by integrating neuromechanical concepts with evidence-based rehabilitation practices.

MATERIAL AND METHODS

This study was conducted as a prospective, assessor-blinded, randomized controlled clinical trial designed to compare the effects of a proprioceptive exercise–based rehabilitation program with those of conventional physical therapy on balance performance in individuals with knee osteoarthritis. The randomized controlled design was selected to minimize selection bias and permit causal inference regarding the comparative effectiveness of the two exercise approaches on balance outcomes, in line with international recommendations for intervention studies in musculoskeletal rehabilitation (33). The trial was carried out at the Physical Therapy Outpatient Department of the National Healthcare Centre, Karachi, Pakistan, between March 27, 2025, and June 13, 2025. Participants were recruited consecutively from patients attending the outpatient clinic during this period. All assessments and intervention sessions were conducted within the same clinical facility to ensure consistency of treatment delivery and outcome measurement. Eligible participants were adults aged 40 years or older with a clinical and radiographic diagnosis of unilateral knee osteoarthritis classified as Kellgren–Lawrence grade 2 or 3. Participants were required to be ambulatory and able to walk independently on level ground for at least 50 feet without the use of assistive devices. Individuals were excluded if they had Kellgren–Lawrence grade less than 2 or greater than 3, a history of knee surgery or total joint replacement, intra-articular corticosteroid injection to the affected knee within the preceding six months, coexisting neurological disorders, vestibular dysfunction, or other musculoskeletal or systemic conditions affecting lower-limb function or balance performance. These criteria were applied to ensure a homogeneous sample representative of individuals with mild to moderate knee osteoarthritis while minimizing confounding from non-osteoarthritic balance impairments.
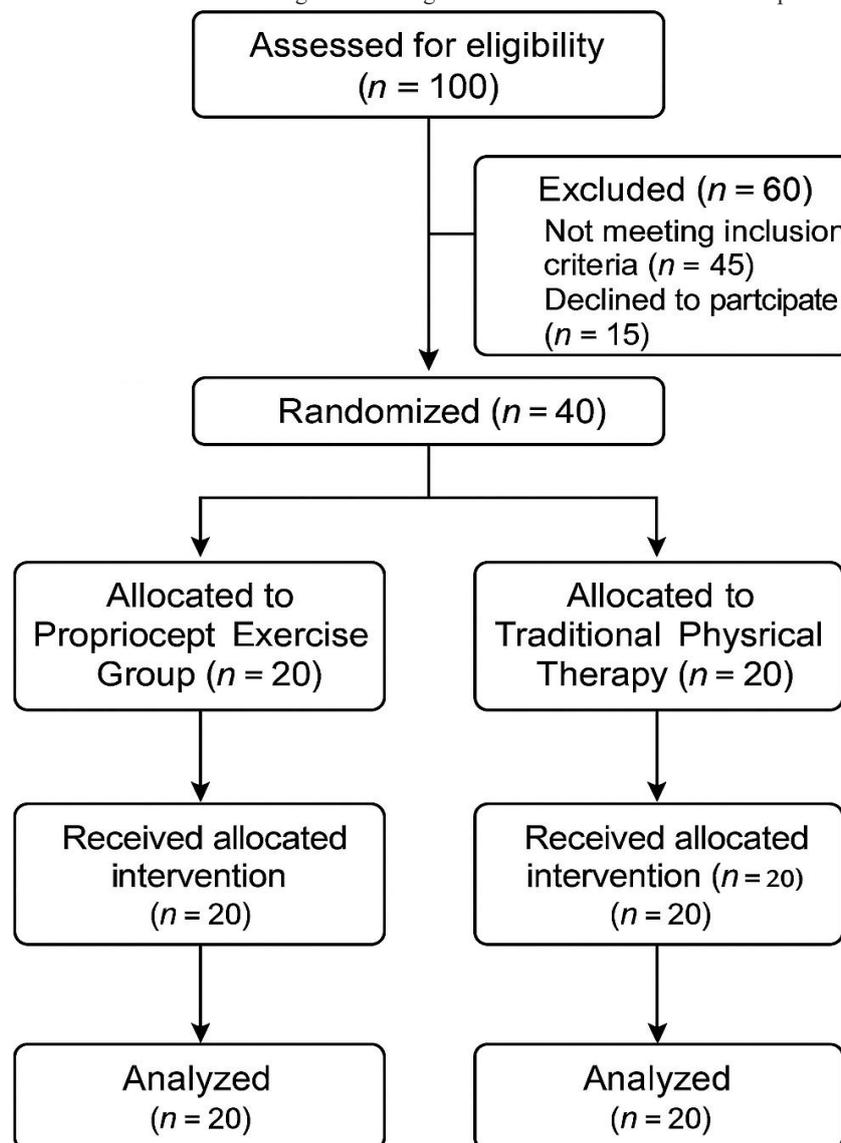
Figure 1 CONSORT Flowchart

Potential participants were screened for eligibility by a licensed physiotherapist with clinical experience in musculoskeletal rehabilitation. Those meeting the eligibility criteria received a detailed explanation of the study procedures, potential risks, and benefits, after which written informed consent was obtained prior to baseline assessment. Enrolled participants were then randomly allocated to one of two intervention groups using a concealed allocation process. Randomization was performed using a computer-generated random sequence prepared by an independent researcher

not involved in participant recruitment, treatment delivery, or outcome assessment. Allocation concealment was ensured through the use of sequentially numbered, opaque, sealed envelopes that were opened only after completion of baseline measurements. Outcome assessors and the statistician responsible for data analysis were blinded to group allocation throughout the study period to reduce detection and analysis bias. Due to the nature of the interventions, blinding of participants and treating therapists was not feasible; however, participants were instructed not to disclose their group allocation to the assessors. A total sample size of 40 participants was determined a priori using G*Power software (version 3.1) based on a repeated-measures analysis of variance model with within–between interaction. Assuming a moderate effect size (f = 0.25), a two-sided alpha level of 0.05, and statistical power of 80%, a minimum sample of 40 participants was required to detect a clinically meaningful difference in balance performance between groups over time (34). Participants were randomly assigned in a 1:1 ratio to the proprioceptive exercise group or the conventional physical therapy group.

Both intervention groups received standardized pulsed ultrasound therapy to the affected knee prior to exercise sessions to control for the potential analgesic and tissue-warming effects of this modality. Ultrasound was applied using a frequency of 1 MHz, intensity of 2 W/cm², duty cycle of 1:4, and duration of five minutes, delivered via a 5 cm² transducer using circular movements over the medial and lateral aspects of the knee joint. Following ultrasound therapy, participants allocated to the proprioceptive exercise group undertook a structured proprioceptive training program consisting of single-leg stance exercises with eyes open and closed, toe walking, heel walking, and cross-body leg swing activities. Exercises were performed under therapist supervision and were designed to challenge static and dynamic postural control through progressive reduction of visual input and increased demands on sensorimotor integration. Each session followed a standardized protocol regarding exercise duration, repetitions, and rest intervals to ensure consistency across participants. Participants in the control group received conventional physical therapy consisting of lower-limb stretching, quadriceps strengthening, and closed kinetic chain functional exercises, including leg press, partial squats, and step-up activities. Exercise selection and dosage were based on commonly used clinical protocols for knee osteoarthritis rehabilitation and were delivered with the same session frequency and overall treatment duration as the proprioceptive exercise group to ensure comparability of intervention exposure. Balance performance was assessed using the Berg Balance Scale, a validated and reliable clinical instrument comprising 14 functional tasks evaluating static and dynamic balance abilities. Each item is scored on a five-point ordinal scale, yielding a total score ranging from 0 to 56, with higher scores indicating better balance performance (35,36). Balance assessments were conducted at four time points: baseline (prior to randomization), Week 4, Week 8, and Week 10 following initiation of the intervention. All assessments were performed by the same blinded assessor to minimize inter-rater variability. Demographic and clinical variables collected at baseline included age, sex, body mass index, affected knee side, and duration of knee pain. These variables were recorded to describe the sample and assess baseline comparability between groups. The primary outcome variable was balance performance as measured by the Berg Balance Scale. Time and group allocation were treated as independent variables in the statistical analysis. Several strategies were employed to reduce bias and enhance internal validity. Randomization and allocation concealment minimized selection bias, while assessor and analyst blinding reduced detection and analysis bias. Standardized intervention protocols and outcome assessment procedures were used to limit performance and measurement bias. Baseline comparability between groups was examined to assess potential confounding, and repeated-measures analysis was selected to account for within-subject correlations over time. Statistical analysis was performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for all variables. A two-way repeated-measures analysis of variance was used to examine the main effects of time, group, and the group-by-time interaction on balance performance. Assumptions of normality and sphericity were assessed prior to analysis, and the Greenhouse–Geisser correction was applied when the assumption of sphericity was violated. Post-hoc pairwise comparisons were conducted using the Holm–Bonferroni adjustment to control for multiple comparisons. Effect sizes were reported using partial eta squared for ANOVA effects and mean differences with 95% confidence intervals for between-group comparisons. All analyses were conducted using a two-tailed significance level of 0.05. The study protocol was approved by the Institutional Review Board of the relevant institution, and all procedures were conducted in accordance with the Declaration of Helsinki. The clinical trial was registered prospectively in a publicly accessible trial registry. Participant confidentiality was maintained throughout the study, and data were stored securely with access restricted to the research team. Standardized data entry procedures and double-checking of datasets were implemented to ensure data accuracy and reproducibility

RESULTS

The baseline characteristics of the 40 enrolled participants demonstrated a demographically and clinically comparable study population. The overall mean age was 55.35 years (SD ± 6.20; range 42–67 years). Males comprised 52.5% (n = 21) of the sample, while females accounted for 47.5% (n = 19). Right knee involvement was slightly more prevalent (55%, n = 22) than left knee involvement (45%, n = 18). Regarding symptom duration, 22.5% of participants (n = 9) reported knee pain for less than one year, 35% (n = 14) for 1–3 years, and 42.5% (n = 17) for more than three years. The mean body mass index was 29.22 kg/m² (SD ± 5.27), with values ranging from 20.00 to 39.00 kg/m², indicating that the majority of participants were overweight. No statistically meaningful imbalances were observed at baseline, supporting comparability between intervention groups.

At baseline, balance performance as measured by the Berg Balance Scale showed no statistically significant difference between groups. The proprioceptive exercise group recorded a mean score of 6.50 ± 0.69, while the conventional physical therapy group demonstrated a mean score of 6.55 ± 0.51. The between-group mean difference was −0.05 (95% CI: −0.18 to 0.08), and this difference was not statistically significant (p = 0.341), with a small effect size (η^2 = 0.024), confirming equivalence prior to intervention.

By Week 4, both groups exhibited improvement in balance; however, the magnitude of change was significantly greater in the proprioceptive exercise group. The mean Berg Balance score in the proprioceptive group improved to 5.05 ± 0.61, compared with 5.55 ± 0.51 in the control group. The mean between-group difference was −0.50 (95% CI: −0.77 to −0.23), reaching statistical significance (p < 0.001) with a large effect size (η^2 = 0.550). At the Week 8 assessment, the divergence between groups further increased. Participants in the proprioceptive exercise group achieved a mean score of 3.85 ± 0.59, whereas those in the control group had a mean score of 4.55 ± 0.51. This resulted in a statistically significant mean difference of −0.70 (95% CI: −0.97 to −0.43; p < 0.001), again associated with a large effect size (η^2 = 0.550), indicating sustained and progressive balance improvement favoring the proprioceptive intervention.

At the completion of the 10-week intervention, the largest between-group difference was observed. The proprioceptive exercise group demonstrated a mean Berg Balance score of 2.20 ± 0.52, while the control group recorded a mean score of 3.20 ± 0.41. The mean difference of −1.00 (95% CI: −1.22 to −0.78) was highly statistically significant (p < 0.001) and reflected a consistently large effect size (η^2 = 0.550), indicating

a clinically meaningful superiority of proprioceptive training over conventional physical therapy. When balance scores were averaged across all time points, the overall mean score for the proprioceptive exercise group was 4.40 ± 0.10, compared with 4.96 ± 0.10 for the control group. The pooled mean difference of -0.56 (95% CI: -0.72 to -0.40) was statistically significant ($p < 0.001$), with a large overall effect size ($\eta^2 = 0.624$), favoring the proprioceptive exercise intervention. Repeated-measures analysis of variance revealed a highly significant overall group effect on balance performance. The comparison between the proprioceptive exercise group and the control group yielded an F-value of 132.98 with degrees of freedom (1, 38), corresponding to $p < 0.001$. The associated effect size was very large ($\eta^2 = 0.823$), indicating that a substantial proportion of the variance in balance outcomes was attributable to group allocation.

**Table 1: Baseline Characteristics of Participants (N = 40)**

Variable	Category	n (%) / Mean ± SD
Age (years)	Mean ± SD (Range)	55.35 ± 6.20 (42–67)
Gender	Male	21 (52.5%)
	Female	19 (47.5%)
Affected Knee Joint	Right	22 (55%)
	Left	18(45%)
Duration of Pain	< 1 year	9 (22.5%)
	1–3 years	14 (35%)
	> 3 years	17 (42.5%)
Body Mass Index (BMI)	Mean ± SD (Range)	29.22 ± 5.27 (20.00–39.00)

Table 2. Comparison of Berg Balance Scores Across Groups

Time Point	PEG (n=20) Mean ± SD	CG (n=20) Mean ± SD	Mean Difference (95% CI)	p-value	Effect Size (η²)
Baseline	6.50 ± 0.688	6.55 ± 0.510	–0.05 (–0.18, 0.08)	0.341	0.024
4th Week	5.05 ± 0.605	5.55 ± 0.510	–0.50 (–0.77, –0.23)	<0.001	0.550
8th Week	3.85 ± 0.587	4.55 ± 0.510	–0.70 (–0.97, –0.43)	<0.001	0.550
10th Week	2.20 ± 0.523	3.20 ± 0.410	–1.00 (–1.22, –0.78)	<0.001	0.550
Overall Mean	4.40 ± 0.097	4.96 ± 0.097	–0.56 (–0.72, –0.40)	<0.001	0.624

Table 3: Overall Group Comparisons for Berg Balance Score

Outcome	Group Comparison	Mean Difference	95% CI (Lower–Upper)	p-value	Overall F-value (df)	Effect Size (η²)
Berg Balance Score	PEG vs. CG	–0.56	–0.72 to –0.40	p < 0.001	132.98 (1, 38)	0.823
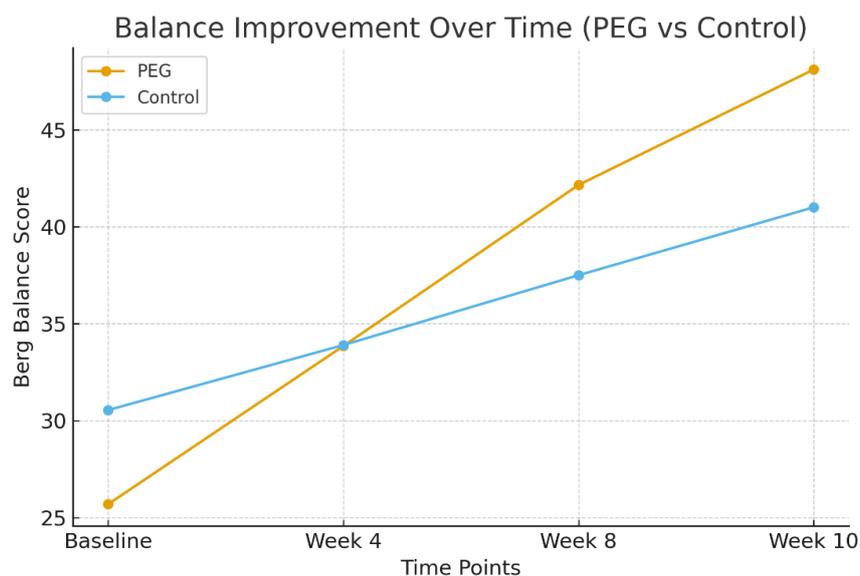
Figure 2 Balance improvement over Time

DISCUSSION

The findings of this randomized controlled trial demonstrate that proprioceptive exercises are significantly more effective than traditional physical therapy for enhancing balance in individuals with knee osteoarthritis (KOA). Participants receiving proprioceptive training exhibited substantial improvements in Berg Balance Scale (BBS) scores across all follow-up intervals—Weeks 4, 8, and 10—compared to those in the conventional therapy group. These improvements were characterized by high effect sizes (), confirming a robust therapeutic impact. While baseline characteristics and initial balance scores showed no statistical difference between groups, the proprioceptive exercise group (PEG) demonstrated

superior gains as early as Week 4, with the disparity becoming even more pronounced by the conclusion of the 10-week intervention. These data align with established pathophysiological evidence suggesting that KOA disrupts proprioception and neuromuscular control due to the degeneration of mechanoreceptors within joint structures (3,8). By specifically targeting these pathways, proprioceptive interventions appear to re-activate neuromuscular control, thereby enhancing joint position sense, dynamic stability, and overall balance responses.

The superiority of proprioceptive training observed in this study is consistent with existing literature highlighting its benefits over conventional rehabilitation. Research by Jeong et al. (2019) and Wang et al. (2021) similarly found that such interventions significantly improve balance, functional stability, and gait parameters in KOA patients, yielding effect sizes comparable to the current findings (10,19). Furthermore, Ince et al. (2022) concluded that female KOA patients engaging in balance and proprioceptive training achieved higher postural stability and a reduced risk of falling compared to those receiving typical physical therapy exercises (12). These observations are supported by Gurudut and Welling (2018) and Gohil and Shukla (2020), who noted marked improvements in proprioceptive acuity and dynamic balance following specialized regimens (14,9). Additionally, trials combining proprioception with manual or strengthening therapies have emphasized the importance of sensory-motor retraining in managing KOA-related impairments (25,26). Meta-analyses further corroborate these results, with Aman et al. (2015) and Lin et al. (2025) reporting significant pooled effects on motor control and functional outcomes, reinforcing the conclusion that proprioceptive-focused programs are more effective than standard care (1,21).

The physiological mechanisms underlying the success of proprioceptive exercises involve the re-education of mechanoreceptor sensitivity, which is often compromised by the afferent feedback interference caused by KOA degeneration. Tasks such as single-leg stances, toe/heel walking, and cross-body leg swings improve the body's response to perturbations, effectively ameliorating center-of-mass control and postural strategies. Furthermore, these exercises enhance muscle co-activation, leading to more efficient neuromuscular recruitment patterns that improve stability around the knee joint. The integration of visual-vestibular feedback during balance training also helps improve multisensory integration, which is vital for patients exhibiting compensatory deficits. These mechanisms align with the neurophysiological models described by Fitzgerald et al. (2011) and Areeudomwong and Buttagat (2019), providing a biologically plausible foundation for the observed clinical improvements (16,33).

These findings have significant implications for clinical rehabilitation, suggesting that proprioceptive training should be considered a core therapeutic element for KOA. Because functional improvements were noted as early as Week 4, these exercises can provide rapid benefits in terms of mobility and fall prevention. The progressive nature of the gains suggests that long-term benefits may be maintained with continued loading. Moreover, since these exercises are cost-effective, safe, and easily implemented in outpatient settings, they represent a high-value intervention for resource-constrained environments. The strengths of this research include its randomized controlled design with blinding and the use of the validated Berg Balance Scale across multiple time points. However, limitations such as the single-center setting, the lack of long-term follow-up beyond 10 weeks, and the restriction to KL grades 2 and 3 should be considered when generalizing these results to more severe KOA populations. In conclusion, this randomized controlled trial confirms that proprioceptive exercises offer a distinct advantage over conventional physical therapy in restoring balance and neuromuscular stability in patients with knee osteoarthritis. By prioritizing sensory-motor retraining, clinicians can achieve faster and more significant improvements in functional mobility and quality of life. Future research should focus on the long-term sustainability of these gains and investigate the impact of these interventions across a broader spectrum of KOA severity using advanced proprioceptive evaluation tools.

CONCLUSION

Proprioceptive training is significantly more effective than conventional physical therapy in improving static and dynamic balance among patients with mild-to-moderate knee osteoarthritis. The 10-week intervention demonstrated that targeted sensorimotor exercises lead to faster and more substantial functional gains, effectively doubling the balance improvement observed in standard care, and should be prioritized as a core component of KOA rehabilitation protocols.

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