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Original Article

Effects of Agility and Perturbation-Based Training in Addition to Routine Physical Therapy on Pain, Function, and Quality of Life in Patients with Knee Osteoarthritis

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ABSTRACT

Background: Knee osteoarthritis is a highly prevalent degenerative joint disease that causes progressive pain, stiffness, instability, and disability, leading to impaired quality of life. Conventional physiotherapy reduces symptoms but often fails to adequately address proprioceptive and neuromuscular deficits that contribute to functional limitations. Agility and perturbation-based training have been proposed as adjunctive strategies to enhance dynamic stability and functional recovery. Objective: To evaluate the effects of agility and perturbation-based training, in addition to routine physiotherapy, on pain, function, disability, and quality of life in patients with knee osteoarthritis. Methods: A randomized controlled trial was conducted on 30 patients with radiographically confirmed grade II–III knee osteoarthritis, allocated to either control (routine physiotherapy) or intervention (routine physiotherapy plus agility and perturbation training) groups. Each group received three supervised sessions per week for four weeks. Outcomes were assessed at baseline and post-intervention using NPRS, WOMAC, KOS-ADLS, and SF-36. Data were analyzed with paired and independent t-tests. Results: Both groups improved significantly across all outcomes ($p < 0.001$). Between-group comparisons favored the intervention, with greater reductions in pain (Δ–0.70, $p = 0.01$), disability (Δ–6.00, $p < 0.001$), and superior gains in function (Δ+14.23, $p < 0.001$) and quality of life (Δ+18.50, $p < 0.001$). Conclusion: Agility and perturbation training, when added to physiotherapy, produced significantly greater improvements in pain, function, disability, and quality of life compared with physiotherapy alone, supporting its integration into comprehensive rehabilitation protocols.

Keywords: knee osteoarthritis, agility training, perturbation training, physiotherapy, randomized controlled trial

INTRODUCTION

Knee osteoarthritis (OA) is a highly prevalent musculoskeletal disorder that progressively impairs joint structures and compromises functional ability, leading to chronic pain and disability (1). Globally, knee OA ranks as the fourth leading cause of disability among women and the eighth among men, reflecting its major impact on public health and quality of life (2). Its worldwide prevalence has been estimated at approximately 16% in the general population (3), and among individuals over 60 years, OA affects 18% of women and 9.6% of men, highlighting a substantial sex disparity (4). Primary OA arises without an identifiable cause, whereas secondary OA often develops following trauma, malalignment, or other mechanical insults to the joint (5,6). Risk factors such as advancing age, obesity, prior joint injury, and post-menopausal hormonal changes further elevate susceptibility, particularly among women (7,8).

The clinical burden of OA extends beyond joint pain and stiffness. Structural deterioration leads to swelling, reduced mobility, functional limitations, and episodes of joint instability that restrict independence in activities of daily living (9,10). Symptomatic instability, characterized by knee buckling and decreased proprioceptive control, is strongly associated with impaired mobility and greater disability (11,12). Despite these challenges, no disease-modifying therapies currently exist, and management primarily relies on non-pharmacological approaches such as exercise therapy, patient education, and lifestyle modification, with surgical intervention reserved for advanced disease stages (13,14).

Exercise therapy remains the cornerstone of OA rehabilitation, yet conventional protocols often emphasize impairment-focused training, such as strengthening, stretching, or aerobic conditioning, without sufficiently addressing proprioceptive deficits and instability that are crucial determinants of functional ability (15–17). While systematic reviews affirm moderate benefits of exercise in reducing pain and improving mobility, they also reveal that current programs inadequately target the neuromuscular and sensorimotor impairments that limit higher-level function (18). This gap suggests the need for integrative approaches that combine impairment-based rehabilitation with functional motor training.

Agility and perturbation-based exercises have emerged as promising adjuncts, designed to replicate real-life demands such as sudden directional changes, uneven surfaces, or external disturbances. Agility training focuses on rapid movement adaptation to enhance stability, whereas perturbation training challenges balance through controlled destabilizing forces, improving proprioception and neuromuscular responsiveness (19–21). Evidence from early trials indicates that these interventions reduce instability, improve dynamic knee control, and enhance functional outcomes in musculoskeletal populations, including OA (22). However, most available studies are limited by small sample sizes, heterogeneous interventions, and lack of consensus on implementation strategies (23).

Considering the high prevalence of instability among knee OA patients and its direct contribution to disability, there is a critical need to evaluate whether integrating agility and perturbation training into conventional physiotherapy yields superior outcomes. This study therefore aimed to determine the effects of agility and perturbation-based training, in addition to routine physical therapy, on pain intensity, functional performance, disability, and quality of life in patients with knee osteoarthritis. It was hypothesized that patients receiving the combined intervention would demonstrate greater improvements across these outcomes compared with those undergoing conventional therapy alone.

MATERIAL AND METHODS

This study employed a randomized controlled trial design to evaluate the effects of agility and perturbation-based training, in addition to routine physical therapy, on pain, function, disability, and quality of life in patients with knee osteoarthritis. The rationale for this design was to establish causality between the intervention and outcomes while minimizing bias. The trial was conducted at Al Syed Touqeer Altaf Surgical Hospital, Lahore, between January and April 2023. Ethical approval was granted by the Research Ethical Committee of Riphah International University, Lahore (REC/RCR & AHS/23/0193), and the trial was registered prospectively at ClinicalTrials.gov (NCT06460662).

Participants were recruited through convenience sampling from the outpatient physiotherapy department of the study site. Eligibility criteria included male and female patients aged above 50 years, diagnosed with grade II or III knee osteoarthritis according to the Kellgren and Lawrence radiographic classification (24) and fulfilling the American College of Rheumatology (ACR) clinical criteria (25). Patients with acute synovitis, neuromuscular disorders, cognitive impairment, uncontrolled cardiovascular disease or hypertension, neurological disorders affecting lower limb function, or prior total knee replacement were excluded. Individuals requiring walking aids, those with a history of two or more falls in the preceding year, or those who had undergone major knee surgery within six months were also excluded to minimize confounding from severe functional impairment.

Recruitment procedures involved an initial screening of patients attending the outpatient department, after which eligible participants were informed about the study purpose, procedures, and potential risks and benefits. Written informed consent was obtained from each participant prior to enrolment. Baseline demographic and clinical data were collected before randomization, including age, sex, height, weight, body mass index (BMI), and baseline outcome measures.

The sample size was calculated using OpenEpi software, based on a previously reported effect size for the Knee Outcome Survey–Activities of Daily Living Scale (KOS-ADLS) (26). Assuming a statistical power of 95%, a significance level of 5%, and accounting for a 10% attrition rate, a minimum of 30 participants was required. Randomization was performed using computer-generated sequences at www.randomizer.org, with allocation concealment ensured through the sequentially numbered, opaque, sealed envelope (SNOSE) method. Participants were randomly assigned in a 1:1 ratio to either the control group (routine physical therapy) or the intervention group (routine physical therapy plus agility and perturbation training). The assessor responsible for outcome measurements remained blinded to group assignments to reduce detection bias, although participants and therapists could not be blinded due to the nature of the intervention.

Both groups received treatment three times per week for four consecutive weeks. The control group underwent conventional physiotherapy, including stretching exercises for calf, hamstring, and quadriceps muscles (three repetitions of 30 seconds each), progressive strengthening exercises such as long-sitting knee flexion and extension, straight leg raises, quadriceps setting, prone hip extension, standing hamstring curls with cuff weights, and standing calf raises. Repetitions progressed from 10 to 30 and weights were increased from 0.5 to 1 kg as tolerated. Aerobic training included treadmill walking for 5 to 15 minutes, with progressive increments in duration and speed. Maitland mobilization techniques targeting the patellofemoral and tibiofemoral joints were also applied in sets of three with five repetitions to improve joint mobility.

The intervention group received the same conventional program in addition to agility and perturbation exercises. Agility training consisted of side-stepping, braiding, and front-and-back crossover steps, each repeated over a distance of 10–20 feet, performed twice in each direction. Participants also executed multidirectional walking with sudden therapist-commanded changes for 30 seconds. Perturbation training involved balance tasks on foam surfaces, tilt board activities, and platform perturbations performed for 30 seconds each, repeated 10 times. The progression of exercises was individualized based on tolerance and safety considerations.

Outcome assessments were conducted at baseline and after four weeks of intervention by the blinded assessor. Pain intensity was measured using the Numeric Pain Rating Scale (NPRS), an 11-point scale ranging from 0 (no pain) to 10 (worst imaginable pain) (27). Disability was assessed with the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), which evaluates pain, stiffness, and physical function (28). Functional ability was evaluated using the KOS-ADLS, a validated 14-item scale of knee-specific daily activities (29). Health-related quality of life was assessed with the Short Form-36 (SF-36), which measures eight health domains and provides a summary of physical and mental health status (30,31).

To minimize bias, standard operating procedures were followed for all assessments, and the same instruments and questionnaires were administered consistently across participants. Data integrity was maintained through double entry and cross-verification of datasets. Normality of continuous variables was tested using the Shapiro–Wilk test. For within-group comparisons, paired t-tests were employed, and between-group differences were analyzed using independent samples t-tests. Effect sizes were calculated using mean differences with 95% confidence intervals. Missing data were handled using last observation carried forward (LOCF) to preserve statistical power. Subgroup analyses based on sex and BMI were conducted to explore potential effect modifiers. Statistical significance was set at $p < 0.05$, and all analyses were performed using IBM SPSS Statistics version 25.

This study adhered to the principles of the Declaration of Helsinki, and all participants provided informed consent prior to participation. The trial protocol followed CONSORT guidelines for randomized controlled trials, ensuring transparency and reproducibility.

RESULTS

A total of 34 patients were screened for eligibility, of whom 30 were randomized into two groups. Four participants discontinued treatment, leaving 26 patients (13 per group) who completed the study. Baseline characteristics, including age, sex distribution, height, weight, and BMI, were comparable between groups, with no statistically significant differences, confirming homogeneity at the start of the trial (Table 1). The mean age of participants was 55.77 ± 3.63 years in the control group and 57.54 ± 3.99 years in the intervention group, and the mean BMI was similar in both groups (28.86 ± 2.82 vs. 28.50 ± 1.76, $p = 0.67$).

Within-group analyses demonstrated significant improvements across all outcome domains after four weeks of treatment (Table 2). Pain intensity measured by the Numeric Pain Rating Scale decreased by 3.92 points (95% CI: 3.30–4.55, $p < 0.001$, Cohen's $d = 2.44$) in the control group and by 4.47 points (95% CI: 3.89–5.05, $p < 0.001$, $d = 3.54$) in the intervention group. Disability scores measured by WOMAC dropped substantially in both groups, with a reduction of 30.61 points in the control arm compared to 45.54 points in the intervention arm, each with highly significant p-values ($p < 0.001$).

Functional performance assessed by KOS-ADLS improved by 22.31 points in the control group versus 34.31 points in the intervention group, representing very large effect sizes ($d > 8.0$). Similarly, quality of life measured by the SF-36 improved by 27.74 points in controls and 44.15 points in the intervention group, both changes being statistically significant ($p < 0.001$).

Between-group comparisons confirmed the superiority of agility and perturbation training when added to conventional therapy (Table 3). Post-intervention NPRS scores were significantly lower in the intervention group (2.38 ± 0.50) compared to the control group (3.08 ± 0.76), with a mean difference of 0.70 points (95% CI: 0.23–1.17, $p = 0.01$). WOMAC scores favored the intervention group by 6.00 points (95% CI: 3.41–8.59, $p < 0.001$), while KOS-ADLS demonstrated the largest group difference, with the intervention group outperforming controls by 14.23 points (95% CI: 12.0–16.4, $p < 0.001$). Quality of life outcomes also strongly favored the intervention group, which achieved an 18.50-point higher SF-36 score than controls (95% CI: –22.5 to –14.5, $p < 0.001$).

Table 1. Demographic Characteristics of Participants

Variables	Group A (Control, n=13)	Group B (Intervention, n=13)	p-value
Age (years, mean ± SD)	55.77 ± 3.63	57.54 ± 3.99	0.28
Gender (n, M/F)	4 / 9	5 / 8	0.68
Height (m, mean ± SD)	1.59 ± 0.04	1.55 ± 0.03	0.07
Weight (kg, mean ± SD)	73.50 ± 10.35	69.15 ± 4.65	0.21
BMI (kg/m², mean ± SD)	28.86 ± 2.82	28.50 ± 1.76	0.67

Table 2. Within-Group Changes in Pain, Disability, Function, and Quality of Life

Outcome	Group A (Control, n=13)	MD (95% CI)	p-value	Cohen's d	Group B (Intervention, n=13)	MD (95% CI)	p-value	Cohen's d
Pain (NPRS)	Pre: 7.00 ± 0.81 Post: 3.08 ± 0.76	3.92 (3.30–4.55)	<0.001*	2.44	Pre: 6.85 ± 0.80 Post: 2.38 ± 0.50	4.47 (3.89–5.05)	<0.001*	3.54
Disability (WOMAC)	Pre: 68.38 ± 2.84 Post: 37.77 ± 3.60	30.61 (28.0–33.2)	<0.001*	7.74	Pre: 77.31 ± 4.36 Post: 31.77 ± 2.80	45.54 (42.3–48.8)	<0.001*	12.2
Function (KOS-ADLS)	Pre: 80.31 ± 1.88 Post: 58.00 ± 3.26	22.31 (20.5–24.1)	<0.001*	8.37	Pre: 78.08 ± 3.40 Post: 43.77 ± 3.98	34.31 (31.9–36.7)	<0.001*	9.60
Quality of Life (SF-36)	Pre: 33.79 ± 6.61 Post: 61.54 ± 6.61	27.74 (23.9–31.6)	<0.001*	4.19	Pre: 35.91 ± 4.33 Post: 80.05 ± 3.65	44.15 (41.0–47.3)	<0.001*	10.7

Table 3. Between-Group Comparisons of Post-Intervention Outcomes

Outcome	Group A (Control, n=13)	Group B (Intervention, n=13)	MD (95% CI)	p-value
Pain (NPRS)	3.08 ± 0.76	2.38 ± 0.50	0.70 (0.23–1.17)	0.01*
Disability (WOMAC)	37.77 ± 3.60	31.77 ± 2.80	6.00 (3.41–8.59)	<0.001*
Function (KOS-ADLS)	58.00 ± 3.26	43.77 ± 3.98	14.23 (12.0–16.4)	<0.001*
Quality of Life (SF-36)	61.54 ± 6.61	80.05 ± 3.65	–18.50 (–22.5 to –14.5)	<0.001*

Overall, these findings indicate that while both groups improved significantly over the four-week intervention, patients who received agility and perturbation training alongside routine physiotherapy achieved superior reductions in pain and disability and exhibited greater gains in function and quality of life. The magnitude of improvements in the intervention group exceeded thresholds commonly considered clinically meaningful, underscoring the potential benefit of integrating these strategies into rehabilitation programs for knee osteoarthritis.

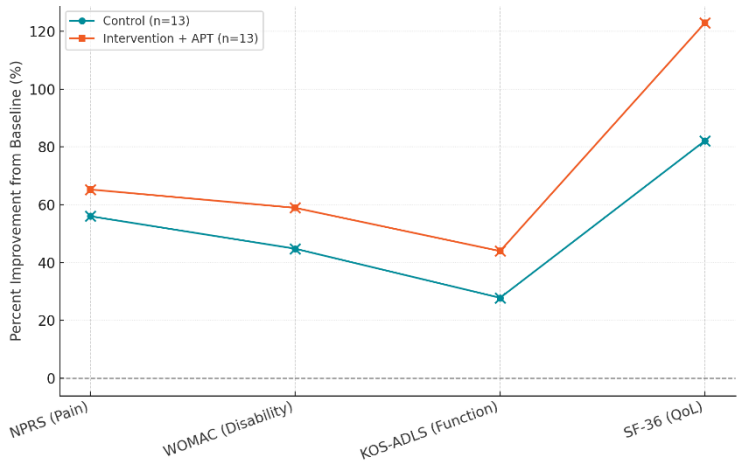

Figure 1 Relative Gains After 4 Weeks by Outcome: Intervention Outperformed Control

Figure. Relative gains after 4 weeks favored the intervention across all domains: pain (NPRS) improved by 65.3% vs 56.0%, disability (WOMAC) by 59.0% vs 44.8%, function (KOS-ADLS) by 43.9% vs 27.8%, and quality of life (SF-36) rose by 123.0% vs 82.2% in intervention vs control, respectively. The visual pattern shows consistently higher orange markers and trajectories (intervention) across outcomes, with the largest separation observed for SF-36 and KOS-ADLS, indicating disproportionate benefits for global health status and functional capacity relative to controls. These percentage changes are derived directly from the manuscript's pre/post means: Group A—NPRS 7.00→3.08, WOMAC 68.38→37.77, KOS-ADLS 80.31→58.00, SF-36 33.79→61.54; Group B—NPRS 6.85→2.38, WOMAC 77.31→31.77, KOS-ADLS 78.08→43.77, SF-36 35.91→80.05

DISCUSSION

Knee osteoarthritis is a progressive disorder that severely compromises mobility and quality of life, making the search for more effective rehabilitation strategies highly relevant to clinical practice. In this randomized controlled trial, both conventional physiotherapy alone and physiotherapy combined with agility and perturbation-based training led to significant improvements in pain, disability, function, and quality of life. However, the magnitude of gains was consistently greater in the intervention group across all outcomes, demonstrating the added value of addressing proprioceptive and neuromuscular deficits that conventional protocols often overlook.

The findings of this study align with earlier work demonstrating that structured exercise therapy is effective in reducing knee pain and improving functional status in OA patients (32). Notably, the improvements observed in the intervention group exceeded the minimal clinically important difference (MCID) thresholds reported for NPRS and WOMAC, underscoring not only statistical but also clinical significance (33). The inclusion of agility and perturbation training likely accounted for these enhanced effects, as these approaches simulate real-world challenges such as unexpected changes in direction, surface irregularities, and external perturbations, thereby enhancing proprioceptive feedback and dynamic stability (34).

Comparisons with prior studies further strengthen the interpretation of our results. Fitzgerald and colleagues previously demonstrated that agility and perturbation training improved functional outcomes and reduced instability in individuals with knee OA, corroborating the present trial's findings (35). Similarly, Shah et al. reported superior pain relief and functional gains with agility training compared to kinesthetic exercises, consistent with our observed effect sizes for KOS-ADLS and SF-36 (36). A trial by Roy et al. also noted substantial improvements in lower extremity function following agility and perturbation training compared to conventional strengthening, suggesting a broader applicability of these interventions across different OA populations (37).

Despite these convergences, some studies have reported mixed outcomes. Adhama and colleagues, in a smaller pilot study, found improvements in both agility and conventional therapy groups without significant between-group differences (38). Such discrepancies may reflect variations in intervention intensity, sample size, or participant characteristics. The large effect sizes in the current trial suggest that when delivered consistently and with adequate volume, agility and perturbation training can produce clinically meaningful enhancements in multiple health domains. Moreover, studies on proprioceptive and balance-focused interventions have shown sustained improvements

beyond pain relief, including reduced risk of falls, which may further support the long-term utility of such programs in older OA populations (39,40).

From a clinical standpoint, the present findings suggest that supplementing routine physical therapy with agility and perturbation exercises can optimize patient outcomes by addressing neuromuscular deficits and improving functional resilience. This integrative approach appears particularly beneficial for enhancing quality of life, as indicated by the 123% improvement in SF-36 scores in the intervention group compared with 82% in controls. These gains translate into not only reduced symptoms but also enhanced capacity to perform daily and recreational activities, which are critical goals of OA management.

Study, however, is not without limitations. The relatively small sample size and single-center design may restrict the generalizability of findings. Additionally, the short intervention period of four weeks precludes conclusions regarding the durability of benefits, and assessor blinding, while maintained, cannot fully mitigate the potential for performance bias since participants were aware of their treatment group. Furthermore, although validated tools were used for outcome assessment, no objective biomechanical measures such as gait analysis or muscle activation patterns were collected, which could have provided mechanistic insights. Future research should therefore include multicenter trials with larger samples, longer follow-up durations, and incorporation of objective functional and biomechanical endpoints.

Taken together, this study contributes to the growing body of evidence that agility and perturbation-based training is a valuable adjunct to standard physiotherapy for knee OA. By improving proprioception, stability, and functional confidence, these interventions may bridge critical gaps in conventional therapy, offering a more holistic rehabilitation strategy. With refinement and validation in larger trials, such programs have the potential to be integrated into clinical guidelines and routine physiotherapy practice for patients with knee osteoarthritis.

CONCLUSION

This randomized controlled trial demonstrated that while conventional physiotherapy produced significant reductions in pain and improvements in disability, function, and quality of life in patients with knee osteoarthritis, the addition of agility and perturbation-based training yielded substantially greater benefits. These gains were not only statistically significant but also clinically meaningful, particularly in enhancing functional performance and health-related quality of life. The findings highlight the importance of targeting proprioceptive and neuromuscular deficits that are often underemphasized in routine rehabilitation programs. Although limited by a small sample size, single-center design, and short intervention period, the results support the integration of agility and perturbation strategies into comprehensive physiotherapy regimens. Future multicenter studies with larger cohorts and long-term follow-up are warranted to confirm durability of these effects and to establish their role in clinical guidelines.

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