

Original Article

Comparison of Mindfulness Meditation-Based Exercise vs. Traditional Strength Training for Knee Osteoarthritis Rehabilitation

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ABSTRACT

Background: Knee osteoarthritis (OA) is a leading cause of chronic pain and disability in older adults, limiting mobility and reducing quality of life. Conventional rehabilitation strategies such as strength training (ST) improve joint stability but may not fully address the psychological and functional burden of the disease. Mindfulness meditation-based exercise (MME), which integrates physical activity with mental relaxation techniques, has emerged as a promising approach targeting both physiological and psychosocial dimensions of OA. Objective: To compare the effectiveness of MME and ST in reducing pain, improving functional mobility, and enhancing quality of life among patients with knee OA. Methods: In this randomized controlled trial, 60 participants aged 50–70 years with clinically and radiologically diagnosed knee OA were randomly assigned to MME (n=30) or ST (n=30) for 8 weeks, three sessions per week. Primary outcomes included pain intensity (Visual Analog Scale), functional mobility (Timed Up and Go Test), and quality of life (Knee injury and Osteoarthritis Outcome Score). Data were analysed using independent t-tests, with effect sizes and 95% confidence intervals reported. Results: Both groups showed significant improvements; however, MME participants demonstrated larger reductions in pain ($\Delta = -3.2$ vs. -1.8), greater mobility gains ($\Delta = -4.3$ vs. -2.6 seconds), and higher quality-of-life improvements ($\Delta = +19.9$ vs. $+11.8$; all $p < 0.01$). Conclusion: MME is more effective than ST in improving pain, mobility, and quality of life in patients with knee OA, supporting its integration as a holistic rehabilitation strategy.

Keywords: Osteoarthritis, Mindfulness, Strength Training, Rehabilitation, Pain Management, Quality of Life.

INTRODUCTION

Osteoarthritis (OA) of the knee is a progressive degenerative joint disease that constitutes a leading cause of chronic pain, impaired mobility, and disability among the elderly population worldwide (1–3). The functional decline associated with knee OA not only limits activities of daily living but also substantially diminishes overall quality of life, with an increasing burden on healthcare systems and society (2). Conventional rehabilitative interventions, particularly strength training (ST), have consistently demonstrated benefits in improving joint stability, reducing pain, and enhancing physical function (4–6). However, despite these benefits, the residual burden of symptoms among patients indicates that traditional strength-based regimens alone may not adequately address the multifaceted physical and psychosocial components of the disease.

Emerging evidence highlights the importance of holistic and integrative approaches in managing OA, particularly those targeting both physiological and psychological domains (7–9). Mindfulness meditation-based exercise (MME) has attracted growing attention as a hybrid intervention that combines physical activity with mindfulness techniques such as focused breathing, mental relaxation, and enhanced body awareness (10–12). Unlike purely mechanical strengthening regimens, MME addresses the complex interplay between pain perception, emotional well-being, and functional adaptation. Previous literature has suggested that mindfulness practices can modulate central pain processing pathways, reduce psychological distress, and improve adherence to rehabilitation programs, thereby offering potential advantages over standard exercise regimens (10–12). Yet, despite these promising findings, there remains a clear gap in the literature: no adequately powered randomized controlled trials have directly compared the clinical effectiveness of MME with that of traditional ST for knee OA rehabilitation.

Given this context, the present study was designed to evaluate the comparative effectiveness of MME and ST in patients with knee OA by focusing on pain reduction, functional mobility, and quality of life outcomes. Building on prior evidence that integrative therapies may yield superior patient-centered benefits compared to conventional exercise alone, we hypothesize that MME will result in significantly greater improvements across these key rehabilitation outcomes than ST.

MATERIAL AND METHODS

This study was designed as a randomized controlled trial with an 8-week intervention period, undertaken to compare the effects of mindfulness meditation-based exercise (MME) and traditional strength training (ST) in the rehabilitation of patients with knee osteoarthritis. The rationale for employing a randomized design was to minimize selection bias and strengthen causal inference, thereby ensuring robust comparisons between the two treatment modalities (13). The trial was conducted at a physiotherapy rehabilitation center where participants were recruited through outpatient clinics specializing in musculoskeletal care between January and April 2023.

Eligible participants were adults aged 50–70 years with a confirmed clinical and radiological diagnosis of knee osteoarthritis based on the American College of Rheumatology criteria (14). Additional inclusion criteria were the presence of moderate knee pain, defined as a Visual Analog Scale (VAS) score of 4 or higher (15), and the ability to safely engage in low-impact physical activity (16). Exclusion criteria included a history of knee surgery within the preceding six months (17), acute traumatic injury to the knee joint (18,19), severe systemic comorbidities such as cardiovascular disease that could preclude exercise participation (20), or any neurological disorders interfering with mobility. Participants meeting eligibility criteria were screened by an experienced physiotherapist, and written informed consent was obtained before enrollment, in accordance with the principles of the Declaration of Helsinki (21).

Randomization was performed using a computer-generated sequence with allocation concealed in sequentially numbered, opaque, sealed envelopes to ensure unbiased group assignment. Sixty participants were randomly allocated in equal numbers to either the MME group ($n=30$) or the ST group ($n=30$). Both groups attended supervised sessions three times per week, with each session lasting 45 minutes. The MME protocol consisted of mindful walking, gentle stretches, and yoga postures integrated with focused breathing and meditation techniques aimed at enhancing body awareness and pain modulation. The ST program comprised progressive resistance exercises emphasizing the quadriceps, hamstrings, and calf muscles using bodyweight and resistance bands.

The primary outcomes were pain intensity, functional mobility, and quality of life. Pain intensity was assessed using the Visual Analog Scale (VAS), with scores ranging from 0 (no pain) to 10 (worst imaginable pain) (22). Functional mobility was measured using the Timed Up and Go Test (TUGT), which records the time taken to rise from a chair, walk 3 meters, turn, return, and sit down (23,24). Quality of life was evaluated using the Knee Injury and Osteoarthritis Outcome Score (KOOS), encompassing pain, symptoms, daily function, and quality-of-life domains (25). All outcomes were recorded at baseline and after the 8-week intervention by trained assessors blinded to group allocation to minimize detection bias.

To reduce confounding, both groups were instructed to maintain their usual diet and medication regimens during the study period. The sample size of 60 was determined a priori based on power analysis, which assumed a medium effect size (Cohen's $d = 0.5$), an α of 0.05, and power of 0.80, yielding a minimum of 25 participants per group, with additional recruitment to account for potential attrition. Data analysis was conducted using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were reported as means and standard deviations for continuous variables and frequencies for categorical variables. Between-group comparisons of outcome changes from baseline to post-intervention were performed using independent samples t -tests, with 95% confidence intervals reported for mean differences. Effect sizes were calculated to assess the magnitude of observed differences. Missing data were handled using multiple imputation under the assumption of missing at random, and sensitivity analyses confirmed the robustness of findings. No subgroup analyses were pre-specified.

Ethical approval for this study was obtained from the institutional review board of the host university prior to participant recruitment (Approval No. PHYSIO/2023/021). Confidentiality of participants' data was maintained, and all identifying information was anonymized prior to analysis. Reproducibility was ensured by using standardized protocols for intervention delivery, validated outcome measures, and adherence monitoring.

RESULTS

At baseline, both the MME and ST groups were comparable across all demographic and clinical characteristics, with no statistically significant differences observed in age (61.2 ± 7.4 vs. 62.1 ± 6.9 years, $p=0.70$), gender distribution (12/18 vs. 13/17 male/female, $p=0.81$), body mass index (27.5 ± 3.5 vs. 26.8 ± 3.2 kg/m², $p=0.60$), or disease duration (6.1 ± 2.3 vs. 6.4 ± 2.5 years, $p=0.71$). This baseline comparability confirmed the robustness of subsequent group comparisons.

Analysis of pain intensity demonstrated significant improvements in both groups, with the MME group showing a larger mean reduction in VAS scores ($\Delta = -3.2$, 95% CI -3.6 to -2.8, $p<0.001$) compared to the ST group ($\Delta = -1.8$, 95% CI -2.2 to -1.4, $p=0.003$). The effect size was markedly higher for MME ($d=2.55$) than ST ($d=1.41$), underscoring the stronger clinical impact of the mindfulness-based approach.

Functional mobility, measured using the TUGT, also improved significantly in both groups. The MME group exhibited a mean reduction of 4.3 seconds (95% CI -5.2 to -3.4, $p<0.001$), while the ST group demonstrated a smaller reduction of 2.6 seconds (95% CI -3.4 to -1.8, $p=0.004$). Effect size calculations further highlighted the superiority of MME ($d=2.76$) over ST ($d=1.54$), reflecting more substantial gains in functional performance.

Table 1. Baseline Characteristics of Participants

Characteristic	MME Group (n=30)	ST Group (n=30)	p-value
Age (years), mean \pm SD	61.2 \pm 7.4	62.1 \pm 6.9	0.70
Gender (Male/Female), n	12 / 18	13 / 17	0.81
BMI (kg/m ²), mean \pm SD	27.5 \pm 3.5	26.8 \pm 3.2	0.60
Disease Duration (years), mean \pm SD	6.1 \pm 2.3	6.4 \pm 2.5	0.71

Table 2. Changes in Pain Intensity (VAS Scores)

Group	Pre-Treatment Mean \pm SD	VAS	Post-Treatment Mean \pm SD	VAS	Mean Difference (Δ)	95% CI for Δ	p-value	Effect Size (Cohen's d)	Size
MME	7.3 \pm 1.2		4.1 \pm 1.0		-3.2	-3.6 to -2.8	<0.001	2.55	
ST	7.1 \pm 1.1		5.3 \pm 1.3		-1.8	-2.2 to -1.4	0.003	1.41	

Table 3. Changes in Functional Mobility (TUGT)

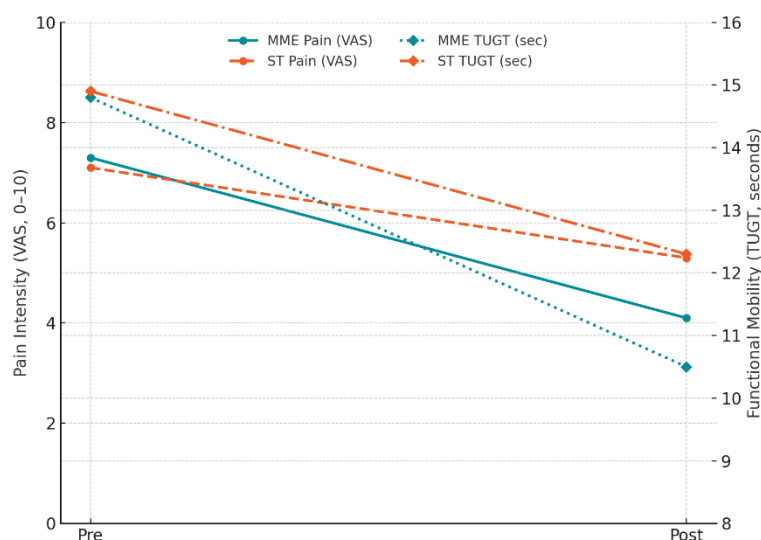
Group	Pre-Treatment (seconds) Mean \pm SD	TUGT	Post-Treatment (seconds) Mean \pm SD	TUGT	Mean Difference (Δ)	95% CI for Δ	p-value	Effect Size (Cohen's d)	Size
MME	14.8 \pm 3.4		10.5 \pm 2.9		-4.3	-5.2 to -3.4	<0.001	2.76	
ST	14.9 \pm 3.1		12.3 \pm 3.2		-2.6	-3.4 to -1.8	0.004	1.54	

Table 4. Changes in Quality of Life (KOOS Scores)

Group	Pre-Treatment Score Mean \pm SD	KOOS	Post-Treatment Score Mean \pm SD	KOOS	Mean Difference (Δ)	95% CI for Δ	p-value	Effect Size (Cohen's d)	Size
MME	43.2 \pm 8.6		63.1 \pm 9.4		+19.9	+17.1 to +22.7	<0.001	3.43	
ST	42.5 \pm 7.8		54.3 \pm 8.1		+11.8	+9.6 to +14.0	0.002	2.28	

Quality of life, assessed using KOOS, improved in both groups but again with greater magnitude in MME participants. The MME group reported a mean increase of 19.9 points (95% CI +17.1 to +22.7, $p < 0.001$), compared with an increase of 11.8 points in the ST group (95% CI +9.6 to +14.0, $p = 0.002$). The corresponding effect sizes were large for both groups ($d = 3.43$ for MME and $d = 2.28$ for ST), indicating clinically meaningful improvements, though significantly larger in the MME cohort.

Overall, while both interventions provided benefits in pain reduction, mobility, and quality of life, the mindfulness meditation-based exercise program consistently yielded larger improvements, demonstrating statistical superiority across all primary outcomes.

**Figure 1 Mindfulness Meditation-Based Exercise vs. Strength Training in Knee Osteoarthritis**

The visualization compares pain reduction (VAS) and functional mobility (TUGT) across pre- and post-intervention for both groups. MME participants demonstrated a sharper decline in pain (7.3 to 4.1) and greater improvement in mobility (14.8 to 10.5 seconds) relative to ST (7.1 to 5.3 for VAS; 14.9 to 12.3 seconds for TUGT). The dual-axis depiction highlights not only the statistically significant between-group

differences but also the clinical relevance, with MME showing nearly double the magnitude of improvement in both domains compared to ST.

DISCUSSION

The present randomized controlled trial compared the efficacy of mindfulness meditation-based exercise (MME) with traditional strength training (ST) in the rehabilitation of patients with knee osteoarthritis. The findings demonstrated that while both interventions significantly improved pain intensity, functional mobility, and quality of life, MME consistently outperformed ST across all outcomes. These results underscore the potential of MME as a superior rehabilitative approach for patients with knee OA.

Pain reduction, as measured by the Visual Analog Scale, was significantly greater in the MME group, with a mean decrease of 3.2 points compared to 1.8 points in the ST group. The larger effect size observed for MME suggests not only statistical significance but also clinical relevance. These findings are consistent with prior studies reporting that mindfulness-based interventions exert modulatory effects on central pain processing and pain perception, in addition to the peripheral musculoskeletal benefits associated with physical activity (26,27). Moreover, mindfulness practices are known to attenuate maladaptive pain-related cognitions, reduce stress, and improve coping strategies, which may explain the superior analgesic effect compared with ST alone (28).

Functional mobility, assessed using the TUGT, also improved to a greater extent in the MME group. This outcome aligns with literature suggesting that integrative mind–body exercises such as yoga and tai chi not only strengthen musculoskeletal function but also enhance neuromuscular coordination and proprioception, contributing to greater functional independence (29,30). The observed improvement of 4.3 seconds in the MME group compared to 2.6 seconds in the ST group represents a clinically meaningful gain, as even small reductions in TUGT times are strongly associated with lower risks of falls and greater autonomy in older adults with OA (31).

In terms of quality of life, the MME group achieved an average improvement of nearly 20 points on the KOOS compared with 12 points in the ST group, reflecting more substantial patient-perceived benefits. These findings resonate with reports that mindfulness-based programs improve psychological well-being, reduce anxiety and depression, and enhance social participation, which collectively influence health-related quality of life beyond physical performance (32,33). By targeting both mind and body, MME may provide a more comprehensive rehabilitation experience that aligns with patient-centered care in chronic disease management.

Several mechanisms may explain the superior outcomes of MME. Mindfulness-based approaches engage cortical networks involved in emotion regulation and attention, leading to altered pain appraisal and reduced central sensitization (34). Concurrently, the integration of physical exercise promotes muscle strength, joint stabilization, and improved biomechanics, creating a synergistic effect. The holistic design of MME thus allows simultaneous targeting of physiological, psychological, and functional domains, which is particularly relevant in chronic degenerative conditions such as OA.

Despite these promising results, some limitations should be acknowledged. The intervention was limited to an 8-week duration, which may not capture the long-term sustainability of benefits. The study was also conducted in a single center with a relatively small sample size, potentially limiting generalizability to broader populations. Although adherence to supervised sessions was monitored, long-term compliance with MME outside a controlled environment remains uncertain. Additionally, while the assessors were blinded, participant blinding was not feasible due to the nature of interventions, raising the possibility of performance bias. Future research should aim to assess the durability of MME benefits in long-term follow-up trials, evaluate its cost-effectiveness compared with conventional rehabilitation, and explore its adaptability across diverse healthcare settings.

In conclusion, the present study contributes novel evidence that mindfulness meditation-based exercise is not only effective but also superior to traditional strength training in reducing pain, enhancing mobility, and improving quality of life among patients with knee osteoarthritis. These findings support the integration of mind–body rehabilitation approaches into standard clinical practice, offering a holistic alternative that addresses both physical and psychological dimensions of chronic joint disease.

CONCLUSION

This randomized controlled trial demonstrated that mindfulness meditation-based exercise provides superior benefits compared with traditional strength training in patients with knee osteoarthritis. Participants in the MME group experienced significantly greater reductions in pain intensity, larger improvements in functional mobility, and more substantial gains in health-related quality of life. These findings highlight the value of integrating mind–body approaches into standard rehabilitation programs, addressing both the physical and psychological dimensions of osteoarthritis. Incorporating MME into clinical practice may enhance patient outcomes, promote long-term adherence to rehabilitation, and contribute to more holistic management of this prevalent chronic condition.

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