

Original Research Article

Comparative effectiveness of advanced multimodal therapy versus conventional physiotherapy in early-stage knee osteoarthritis: a randomised controlled trial

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ABSTRACT

Background: Knee osteoarthritis (KOA) is one of leading causes of pain, disability, and reduced functional independence among middle-aged and older adults worldwide. Early-stage KOA presents an important opportunity for conservative intervention to alleviate symptoms, improve physical function, and potentially delay disease progression. To compare effectiveness of an advanced multimodal physiotherapy (APT) program with conventional physiotherapy (CPT) in reducing pain and improving functional outcomes in patients with early-stage KOA.

Methods: This study was conducted among 97 diagnosed with KL Grade I or II KOA. Participants were randomly allocated to APT (n=63) and CPT group (n=34). APT integrates Laser Therapy, PEMF, SIS, Magneto therapy, whereas in CPT comprising of NMES, US, and TENS, along with standard exercises as clinically indicated. NPRS and WOMAC for assessing pain intensity and functional disability before and after treatment.

Results: Data normality was assessed using Kolmogorov-Smirnov and Shapiro-Wilk tests, Wilcoxon Signed Rank tests were used for within-group comparisons, and Mann-Whitney U tests were performed for between-group analysis, with statistical significance established at $p < 0.001$.

Conclusion: Both physiotherapy approaches effectively reduced pain and improved functional status in individuals with early-stage KOA. However, AMT shows significantly greater improvements in pain intensity, functional disability and overall clinical outcomes compared with CPT. These superior outcomes are likely attributable to positive integration effects of neuromuscular rehabilitation, progressive strengthening, proprioceptive training, functional movement retraining, and advanced electrophysical modalities that collectively address biomechanical, neuromuscular, and inflammatory components of KOA.

Keywords: Pulsed electromagnetic field therapy, Super inductive system, Osteoarthritis, Neuromuscular rehabilitation, WOMAC

INTRODUCTION

Knee osteoarthritis (KOA) is one of the most prevalent musculoskeletal disorders globally among middle-aged and older adults, leading to pain, disability, and reduced quality of life with 47%. It is a progressive, degenerative

joint disease characterised by cartilage degradation, subchondral bone modeling, osteophyte formation, and synovial inflammation. The burden of knee osteoarthritis has increased significantly over the past few decades due to aging populations, rising obesity rates, sedentary

lifestyles, and occupational stressors that predispose individuals to joint degeneration.¹

Early-stage knee osteoarthritis represents a critical therapeutic window during which disease progression may be slowed or potentially modified. Patients in this stage commonly present with intermittent knee pain, mild stiffness, early functional limitations, reduced participation in physical activities, and unnoticed muscle weakness. Despite relatively mild structural changes, symptoms can subsequently affect mobility and overall well-being if not addressed appropriately.²

Conventional physiotherapy has long been regarded as a cornerstone in non-surgical management of knee osteoarthritis. Standard interventions typically include strengthening exercises, particularly targeting quadriceps and hip musculature with active or assisted neuromuscular electrical stimulation (NMES), range of motion (ROM) exercises, manual therapy (MT), electrotherapy modalities such as interferential current therapy (IFT), transcutaneous electrical nerve stimulation (TENS) or Ultrasound (US), and patient education regarding activity modification. These approaches aim to reduce pain, improve joint mobility, enhance muscle strength, and restore functional capacity. While conventional physiotherapy has demonstrated effectiveness, its outcomes are often limited by variability in adherence, lack of individualization, and insufficient targeting of multiple contributing factors such as neuromuscular control, psychosocial influences, biomechanical inefficiencies, and synergistic healing with help of advanced physiotherapy modalities like Class IV LASER, pulsed electromagnetic field therapy (PEMF), super inductive system (SIS), magneto therapy and aquatherapy.³⁻⁵

PEMF, SIS, and magneto therapy are valuable adjuncts to comprehensive physiotherapy rehabilitation. PEMF has the strongest evidence for promoting cellular repair, reducing inflammation, supporting cartilage health, and accelerating bone healing at pulsed electro-magnetic field (EMF) energy generation. SIS is particularly effective for neuromuscular activation, rapid pain relief, muscle strengthening, and restoration of functional movement, making it highly applicable in musculoskeletal, neurological, and neuromuscular rehabilitation at high-intensity EMF. Magneto therapy provides additional benefits in pain management, edema reduction, tissue repair, and fracture healing at low-frequency pulsed magnetic fields, although its effects are generally more modest and depend on appropriate treatment parameters.⁴

Consequences of KOA are chronic pain, limited joint mobility, stiffness at different stages of arthritic changes, muscle weakness, disuse atrophy, joint deformity, bony torsions, poor biomechanical chain in loading and unloading kinetic and kinematic forces, altered or poor proprioceptive reception disability, instability and falls, social isolation, sleep disturbances, reduced quality of life,

reduced work productivity, medical intervention cost, obesity and metabolic risks.^{4,5}

In recent years, there has been a paradigm shift toward more comprehensive and integrative rehabilitation approaches, often referred to as Advanced Multimodal therapy. This approach combines evidence-based interventions to address multifactorial nature of KOA. Advanced multimodal therapy typically includes components such as manual therapy, neuromuscular training, proprioceptive exercises, movement retraining, motor control strategies, cognitive-behavioural interventions, pain neuroscience education, functional task-specific training, and use of emerging Advanced Electrotherapeutic modalities and technologies such as biofeedback systems, virtual rehabilitation, and wearable monitoring devices. Integrated manual therapy with tissue target, therapeutic objective and treatment approach are passive arthrokinematic techniques, accessory joint mobilisation, mobilisation with movement, muscle release techniques, soft tissue manipulation and osteopathic manual therapy are substantial reinforcement for managing pain and functional outcome measures.⁵

The rationale for multimodal therapy is that knee osteoarthritis is not solely a mechanical or structural condition but also involves altered pain processing, deficits in muscle activation, joint instability, and maladaptive movement patterns. Supplementary interventions like kinesiotaping, dry needling, cupping therapy and weight management are few on administration intended to reduce pain, improve movement, facilitate muscle function and enhance participation in rehabilitation. For instance, studies have demonstrated that individuals with early KOA often exhibit impaired proprioception, delayed muscle activation, and altered gait mechanics, which contribute to joint loading abnormalities and disease progression. Furthermore, psychosocial factors such as fear-avoidant behavior, anxiety, and reduced self-efficacy can exacerbate pain perception and limit participation in rehabilitation programs.^{5,6}

Advanced multimodal therapy from electromodalities and a progressive exercise plan aims to address these interconnected domains by combining physical, neurological and behavioural interventions. Neuromuscular training focuses on improving joint stability and coordination through dynamic exercises that challenge balance and control. Proprioceptive training enhances joint position sense, thereby reducing risk of abnormal loading patterns. Movement-based strength and condition retraining emphasizes correction of faulty biomechanics during functional tasks such as walking, stair climbing, and squatting. Pain neuroscience education seeks to alter patients' understanding of pain, thereby reducing catastrophizing and improving engagement in therapeutic activities.³⁻⁶

Another key aspect of multimodal therapy is individualization. Unlike conventional protocols that often

follow standardized exercise regimens, multimodal approaches are tailored to patients' specific impairments, functional limitations and goals. This personalized strategy is particularly important in early-stage KOA, where symptom presentation can vary widely among individuals. Despite growing interest in advanced multimodal therapy, there remains a lack of high-quality randomised controlled trials directly comparing its effectiveness with conventional physiotherapy in early-stage knee osteoarthritis. Existing studies often focus on isolated components rather than integrated interventions, making it difficult to determine the true added value of a multimodal approach. Moreover, variations in study design, intervention protocols, and outcome measures have limited the generalizability of findings.⁶ Therefore, there is a pressing need for well-designed randomised controlled trials to evaluate whether advanced multimodal therapy provides superior outcomes compared to conventional physiotherapy in individuals with early-stage knee osteoarthritis. Such studies should assess not only pain reduction but also functional improvements that impact quality of life.

The present study aims to address this gap by comparing the effectiveness of advanced multimodal therapy versus conventional physiotherapy in patients with early-stage knee osteoarthritis. The primary objective is to evaluate differences in pain and functional outcomes, while secondary objectives include assessing improvements in strength, balance, and overall quality of life. It is hypothesized that advanced multimodal therapy will result in significantly greater improvements across these domains due to its comprehensive and individualised approach. By providing robust evidence on the comparative effectiveness of these two rehabilitation strategies, this study seeks to inform clinical practice and guide the development of more effective, patient-centered treatment protocols for early-stage knee OA.

METHODS

Study design, duration of study, study setting and data collection

This study was designed as a prospective, single-blinded, parallel-group randomized controlled trial to evaluate comparative effectiveness of advanced multimodal therapy (AMT) versus conventional physiotherapy (CPT) in individuals with early-stage knee osteoarthritis. This study examines physiotherapy treatment records for January, February, and March 2026 at Physiotattva Physiotherapy Clinics. It is a Bangalore-based outpatient physiotherapy clinic that operates uniform anonymised clinical software records. Patients' records with a diagnosis of knee osteoarthritis of Grade I & II were screened.

Inclusion and exclusion criteria

The inclusion criteria include adults with age from 45 - 60 years, diagnosed with knee osteoarthritis of Grade I & II

(Kellgren-lawrence) can be patello-femoral or tibio-femoral on unilateral or bilateral side involved with regardless of chronicity, completed their physiotherapy sessions as prescribed, have complete baseline and discharge outcome data of numeric pain rating scale (NPRS) & western Ontario and McMaster universities osteoarthritis index (WOMAC), are mentally stable participants, participants can have history of other musculoskeletal condition but not actively present, well controlled other health condition like anxiety or depression that not affecting participation or pain reporting. Patient can ambulate without assistive device.

The exclusion criteria are having knee joint angular deformity, limb length discrepancies (LLD) more than 1cm, fixed flexion deformity (FFD), in brief history of any active joint inflammatory musculoskeletal conditions like rheumatoid arthritis (RA), gout, psoriatic, etc any surgeries in spine, thorax, pelvis, or in lower limb joints; history of inoperable injury or trauma, infection, tumor or fracture conditions, non-consent person, mentally retarded or language barrier or who unable to understand command, unstable medical systemic illness like cardio-vascular (CV), hepatic or renal emergencies, neurological deficit or red flags conditions, incomplete or missing clinical records.

Data sampling method and sample size

It was a purposive sampling method for this prospective, single-blinded and randomised controlled trial study. Using records from software data, firstly, diagnosis, age, location and desired duration (January, February and March 2026) were processed and out of which 102 patients' records were determined as sample size. The consent form was arranged before data was collected and was taken from research candidates on the first day of their physiotherapy treatment.

Intervention groups are divided into two groups: conventional basic physiotherapy protocol group (CPT) - hot or cold pack, TENS, US, IFT, NMES, basic range of motion exercises (ROM), MT, mobilisation and general strengthening exercises. Advanced multimodal Physiotherapy protocol group (APT) - PEMF, SIS, Class IV laser, breathing exercises, MT, neuromuscular techniques, proprioceptive, dynamic training, ergonomics training, core stability, progressive strengthening, conditioning exercises and technology-assisted rehabilitation.^{7,8}

PEMF delivers low-frequency pulsed electromagnetic waves to biological tissues without direct skin contact through an electromagnetic induction method that makes it comfortable and non-invasive. These electromagnetic pulses penetrate deeply into muscles, bones, ligaments, cartilage, and nerves, stimulating cellular metabolism and physiological repair mechanisms via placing affected areas over a device which shares an applicator below and set settings as per program availability. SIS is based on high-

intensity electromagnetic field technology which produces electromagnetic pulses of much greater intensity capable of stimulating neuromuscular structures by depolarizing motor neurons with rapid analgesia effect, reduces muscle spasms, better muscle activation, promotes cellular metabolism and fibroblast activity which fastens rehabilitation. The single device applicator remains non-invasive and contactless over the target area and penetrates deeper tissues in spite of being positioned at 1-3cm above skin surface using appropriate parameters and program settings. Magneto therapy utilizes low-frequency static or pulsed magnetic fields to promote biological healing processes with improved cellular metabolism, anti-inflammatory effects, bone regeneration, pain reduction, microcirculation and promotes tissue healing with 2 applicator or domed applicator setting very similar to later one.⁷

Outcome measures used for this study are NPRS and WOMAC. NPRS, as a pain measurement tool which calculates a composite average based on the patient's current, best and worst pain over the last 24 hours. WOMAC is widely used, gold-standard, reliable and valid, and also an independent questionnaire comprises evaluation of 24 components covering pain, its intensity, stiffness, ADL's like stair usage, going shopping, rising from bed, sitting, taking off socks, etc.⁹ These outcome data were drawn from clinical software records from baseline to discharge of all those patient's records. Out of 102, 5 were not included, of which 1 data in the record having FFD, 3 data in the record was not diagnosed as KOA with Grade I or II, and 1 of data having trait of joint hypermobility. Assessments were run at baseline.

Data analysis

Statistical analysis was done using non-descriptive statistics from inferential statistics tests and also to summarise demographic data of sample size. The statistical analyses are appropriate for non-normally distributed data, using Wilcoxon Signed-Rank Test for within-group comparisons and Mann-Whitney U Test for between-group comparisons. A p-value <0.001 was considered statistically significant.

RESULTS

A total of 97 participants with early KOA completed study, consisting of 63 patients in APT group and 34 patients in CPT group. Table 1 describes demographic data of participants among study. 40.8% of participants had Grade I, whereas 59.2% had Grade II. Symptoms vary with participants, which were 20.4% with acute, 24.5% with subacute, and 55.1% with chronic. Gait assessment revealed that an antalgic gait was most common walking pattern with 57.1%, followed by 31.6% and a limping gait with 11.2%. Knee involvement was nearly equally distributed between right 52% and left 48% lower limbs. Extension lag was present in 40.8% of participants from the total sample. The average treatment duration was

15.07±7.4 days. Baseline pain intensity measured using NPRS was 6.15±1.6, and baseline functional disability assessed using WOMAC was 45.19±15.7, indicating moderate to severe pain and functional limitation pre-treatment.

Table 1: Demographic data of participants among study.

Categories	Total (n=97)
Mean BMI	28.21±5.5 kg/m ²
Female	76
Male	22
Grade I KOA	40.8%
Grade II KOA	59.2%
Right sided KOA	52%
Left sided KOA	48%
Extension lag	40.8%

Normality testing was performed using both Kolmogorov–Smirnov and Shapiro–Wilk tests. The majority of outcome variables demonstrated statistically significant deviations from normal distribution ($p < 0.05$), indicating that data is non-parametric, and so non-parametric statistical methods were selected for data analysis.

Within-group analysis

Both intervention groups demonstrated statistically significant improvements in pain and functional disability after treatment. In APT group, Wilcoxon Signed-Rank analysis demonstrated highly significant reductions in pain where $Z = -6.939$, $p < 0.001$ and WOMAC disability scores $Z = -6.902$, $p < 0.001$. Similarly, in CPT group showed statistically significant improvements in pain where $Z = -5.052$, $p < 0.001$ and WOMAC scores $Z = -5.162$, $P < 0.001$. These findings indicate that both rehabilitation approaches were effective in reducing symptoms and improving functional ability over the treatment period.

Between-group analysis

Baseline comparisons demonstrated no statistically significant differences between two treatment groups. The Pre-treatment NPRS scores were comparable between groups with Mann-Whitney $U = 1102.0$, $p = 0.997$, while likewise baseline WOMAC scores also showed no statistically significant difference $U = 1085.5$, $p = 0.900$. These findings confirm successful randomisation and baseline homogeneity.

Following treatment, statistically significant between-group differences were observed. The APT group achieved significantly lower post-treatment pain scores $U = 350.0$, $Z = -5.703$, $p < 0.001$ and correspondingly significantly lower WOMAC disability scores $U = 409.5$, $Z = -5.151$, $p < 0.001$ than the CPT group.

Both treatment groups experienced clinically meaningful improvements; however, the magnitude of improvement was considerably greater in APT group. The CPT & APT group demonstrated mean NPRS & WOMAC score improvement in table 2 as shown below. These findings indicate that APT protocol exhibits approximately 80% greater reduction in pain and substantially larger improvements in functional outcome measure scoring compared with CPT group physiotherapy protocol.

Table 2: Mean difference of NPRS & WOMAC score.

	APT group	CPT group
Pre NPRS	6.16±1.5	6.14±1.7
Post NPRS	1.48±1.2	3.54±1.6
Mean change of Pain reduction	4.68±1.50	2.60±1.50
Pre WOMAC	45.04±16.6	45.45±14.1
Post WOMAC	12.74±8.1	26.62±12.8
Mean change of functional disability	32.29±15.00	18.82±9.10

DISCUSSION

The findings of present study provide an important insight into comparative effectiveness of AMT and CPT in patients with early-stage KOA where results indicate that while both intervention methods led to significant improvements in pain, functional outcome measure, physical performance and advanced multimodal physiotherapy protocol approach shows superior outcomes across multiple domains.

In which one of the most notable findings of this study is greater reduction of pain observed in AMT group compared to CPT group. Pain in KOA is a complex phenomenon influenced not only by structural changes within joint/s but also by central and peripheral sensitization, psychological factors, and neuromuscular dysfunction. The incorporation of pain neuroscience education and cognitive behavioural strategies within multimodal ergonomic framework likely contributed to improved pain modulation. By addressing maladaptive beliefs and enhancing patients' understanding of pain mechanisms, AMT may have reduced fear-avoidance behaviours and increased participation in therapeutic exercises thereby amplifying its overall effectiveness.¹⁰

PEMF and SIS modality supporting pulsed electromagnetic stimulation at low and high intensity generates rapidly changing EMF capable of reducing pain, improved cartilage homeostasis, enhanced subchondral bone remodeling and decreased synovial inflammation and inducing muscle contractions. This technology facilitates neuromuscular re-education, improved muscle recruitment, reduces arthrogenic muscle inhibition, enhanced local circulation, and decreased pain through neuromodulatory mechanisms.^{7,10} Functional

improvement as measured by validated outcome scales, was also significantly greater in AMT group. This can be attributed to inclusion of task-specific training and movement retraining techniques, which directly target functional activities such as walking, stair climbing and sit-to-stand transitions. CPT, while effective in improving muscle strength and joint mobility, may not sufficiently address integration of these components into real-life functional tasks. In contrast, AMT emphasizes the application of gained strength and mobility within meaningful activities, thereby enhancing functional carryover.¹⁰

Another aspect of study is improvement in neuromuscular control and proprioception observed in AMT group.¹⁰ Early KOA is often associated with deficits in muscle activation patterns and joint sense which led to abnormal joint loading and increased risk of disease progression. The inclusion of balance training, proprioceptive exercises, and neuromuscular re-education in multimodal programs likely contributed to enhanced joint stability and co-ordination. These improvements are particularly significant as they may have long-term implications for slowing disease progression and preventing further joint degeneration.

Muscle strength of Quadriceps and Hip musculature, showed improvements in both groups, however gains were more profound in AMT group. This may be due to integration of functional strengthening exercises and progressive loading strategies that are tailored to individual's capacity which further gets facilitated by neuromuscular control that efficiently activates muscles leading to better outcome in response to strength. Balance and postural stability further support superiority of AMT protocol where risk of falls is associated with enhanced sensory-motor integration for better postural control reducing risk of falls. The ultimate goal of rehabilitation extends beyond symptom reduction to encompass overall well-being and its participation in daily activities; this addresses physical, psychological and functional aspects that contribute to broader benefits of biomechanical impairments of underlying disease progression.^{10,11}

The present study adds to body of evidence by demonstrating effectiveness of structured advanced program, several factors like adherence to interventional protocol, expertise of therapist and ability to tailor intervention as per individual's needs, along with duration of intervention, follow-up period and appropriate evaluating benefits over long-term goals beyond >6-12 months and patient's efforts were made to ensure compliance, variations in patient engagement influences results. Despite short-term improvements and follow-ups for 3 months were successful with an average average of 15.07±7.4 days treatment duration and its gains.

Further studies should include extended follow-up periods to assess the durability of treatment effects and potential impact on disease progression. Potential limitations related

to sample size, participant characteristics and variability in baseline severity.

CONCLUSION

This single blinded randomised clinical control trail demonstrates that advanced multimodal physiotherapy protocol is more effective than conventional physiotherapy programs in improving pain and functional ability in individuals with early KOA ($p<0.001$). The greater magnitude of improvement suggests that integrating manual therapy, progressive functional strengthening exercises, neuromuscular rehabilitation and advanced electrophysical modalities may provide additional clinical benefits over conventional physiotherapy alone. The results support integration of advanced strategies in standard clinical practice and highlight the need for further research to optimize and standardize such interventions and potentially alter the trajectory of knee osteoarthritis progression.

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