Natural Resources for Human Health
eISSN: 2583-1194

Original Research

**Received** 25 May 2026
**Revised** 28 June 2026
**Accepted** 15 July 2026

Natural Resources for Human Health 2026, Vol. 6 (7s): 172–180

**KEYWORDS**:
diathermy, osteoarthritis, physiotherapy, inflammation, gait

# Comparative Effectiveness of Continuous Versus Pulsed Long-Wave Diathermy in Patients with Knee Osteoarthritis: A Pilot Randomized Study

## Running header: Continuous vs Pulsed Long-Wave Diathermy in Knee OA

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## ABSTRACT:

**Background**: Knee osteoarthritis (OA) is a degenerative musculoskeletal disorder leading to chronic pain and disability. Long-wave diathermy (LWD) is used in physiotherapy practice, but comparative evidence between continuous (CLWD) and pulsed (PLWD) modes is scarce.

**Objective**: To compare the effects of CLWD versus PLWD combined with conventional physiotherapy on pain, range of motion (ROM), function, quality of life, inflammatory biomarker (IL-6), and gait in patients with knee OA.

**Methods**: Thirty patients with grade II–III knee OA were randomized into PLWD (n=15) and CLWD (n=15) groups. Both received identical conventional therapy (ultrasound, hot packs, quadriceps isometrics, hamstring stretching) for 8 weeks, 3 sessions/week. Outcomes included VAS, knee ROM, WOMAC subscales, WHOQOL-BREF, IL-6 levels, and gait parameters. The Shapiro–Wilk test was applied for normality; paired and independent t-tests were used for within- and between-group comparisons at $\alpha = 0.05$.

**Results**: Both groups showed significant improvements ($p < 0.05$). CLWD produced greater reductions in VAS (-5.7 vs -4.6), IL-6 (-3.2 vs -2.0 pg/mL), and WOMAC domains, as well as larger gains in ROM (flexion: +18° vs +11°), WHOQOL domains (physical:

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eISSN: 2583-1194

+32 vs +22), and stride length (+20 cm vs +15 cm). Between-group differences were significant ($p < 0.05$).

Conclusion: Continuous LWD was more effective than pulsed LWD in reducing pain, improving function, enhancing quality of life, and lowering inflammation in knee OA. Larger multicenter RCTs are warranted.

## 1. INTRODUCTION

Knee osteoarthritis (OA)is among the most prevalent musculoskeletal disorders, affecting over 500 million individuals globally and approximately 28–32% of Indian adults above 50 years of age (Li et al., 2024; Vitaloni et al., 2019). It contributes significantly to pain-related disability, reduced mobility, and loss of independence, posing a growing socioeconomic challenge (Hunter & Bierma-Zeinstra, 2019; Fransen, 2015). Non-pharmacological management, particularly physiotherapy, remains the cornerstone of conservative care and is endorsed by international guidelines (Zhang et al., 2020).

Diathermy, a deep-heating electrotherapeutic modality, delivers electromagnetic energy to tissues and produces both thermal and non-thermal effects (Akyol et al., 2010). Among its variants, long-wave diathermy (LWD) operates at 0.3–1 MHz and is increasingly used in musculoskeletal rehabilitation (Berteau et al., 2024). Continuous LWD (CLWD) provides sustained heating that enhances tissue extensibility and circulation, whereas pulsed LWD (PLWD) minimizes heating and emphasizes cellular signaling. While evidence for LWD in knee OA remains limited, studies on short-wave diathermy have shown that continuous delivery yields superior pain relief and functional outcomes (Onigbinde et al., 2013; Ozen et al., 2019; Akyol et al., 2010).

From a comparative-physiology perspective, the mode of energy delivery can determine biological adaptation. Hemodynamic and hematological responses differ between continuous running and intermittent cycling because of changes in mechanical load (Allen et al., 2022). Analogously, CLWD and PLWD may provoke distinct vascular and metabolic responses influencing therapeutic outcomes in knee OA.

This pilot study was therefore designed to compare the effects of CLWD and PLWD, each combined with conventional physiotherapy, in patients with grade II–III knee OA. We hypothesized that CLWD would produce greater improvements in pain, range of motion (ROM), functional status (WOMAC), quality of life (WHOQOL-BREF), inflammatory biomarker levels (IL-6), and gait parameters compared with PLWD.

## 2. MATERIALS AND METHODS

### 2.1 Study Design and Participants

This study was approved by the Institutional Ethics Committee of Amity Institute of Health Allied Sciences, Amity University, Noida (Approval No: AUUP/IEC/JUN/2022/5). The trial was registered prospectively with the Clinical Trials Registry–India (CTRI/2023/05/052912). All procedures adhered to the ethical principles of the Declaration of Helsinki, and written informed consent was obtained from all participants.

The study was designed as a prospective, randomized, controlled pilot trial. Participants were physician-diagnosed with knee OA and recruited from the outpatient clinics of AID Plus Physiotherapy Center, Noida, India, where all interventions and data collection were conducted. Thirty participants with clinically and radiologically confirmed knee OA (Kellgren–Lawrence grade II–III) were enrolled.

Sample size determination: Sample size was determined a priori using G*Power software (version 3.1.9.7). Assuming a moderate effect size ($d = 0.6$), $\alpha = 0.05$, and power $(1–\beta) = 0.80$, a minimum of 12 participants per group was required. To account for possible dropouts, 15 participants per group were recruited, giving a total sample size of 30 (Anand et al., 2025a).

### 2.2 Inclusion and Exclusion Criteria

Inclusion criteria were: (i) adults ≥ 50 years, (ii) unilateral or bilateral physician-diagnosed knee OA as per the American College of Rheumatology criteria, (iii) radiographic grade II or III on the Kellgren–Lawrence classification, and (iv) baseline VAS pain > 5 cm.

Exclusion criteria included: (i) inflammatory arthritis, (ii) recent knee surgery or injection (< 6 months), (iii) neurological conditions affecting gait, (iv) uncontrolled systemic illness, or (v) contraindications to electrotherapy. These criteria are consistent with previous physiotherapy trials and validated recommendations for OA research (Anand et al., 2025a; Collins et al., 2011; Zhang et al., 2020).

**2.3 Randomization and Interventions**

Participants were randomized into two equal groups (n=15 each): Group 1 received pulsed long-wave diathermy (PLWD), while Group 2 received continuous long-wave diathermy (CLWD). Both groups underwent identical conventional physiotherapy consisting of ultrasound therapy (1 MHz, 1.2 W/cm², 6 minutes), moist hot pack application (10 minutes), quadriceps isometric exercises (1×10 repetitions), and hamstring stretching (1×10 repetitions). Interventions were administered three times per week for eight weeks.

*Dosimetry parameters*:

Continuous LWD (CLWD) was delivered at 0.7 MHz frequency and 15 W output power for 10 minutes in continuous mode. The active electrode was moved in slow circular motions over the affected knee, while the inactive electrode was placed on the contralateral hand to complete the circuit. Pulsed LWD (PLWD) used identical frequency with a 20 ms pulse duration and 1:4 duty cycle, yielding an average power of ≈ 4. Skin temperature was monitored subjectively for comfort; no participant reported excessive heat.

*Random sequence generation*: Participants were randomly allocated (1:1) using a computer-generated random number sequence created in Microsoft Excel by an independent researcher.

Allocation concealment mechanism: Concealment was ensured using sequentially numbered, opaque, sealed envelopes prepared by a researcher not involved in recruitment or intervention delivery.

*Blinding:* Outcome assessors were blinded to group allocation, while participants and treating physiotherapists were not blinded due to the nature of the intervention.

**2.4 Outcome Measures**

*Pain:* Measured using the Visual Analog Scale (VAS)—a 10 cm line ranging from 0 ('no pain') to 10 ('worst pain'). The VAS shows excellent test–retest reliability (ICC = 0.97) in musculoskeletal disorders (Hawker et al., 2011).

Knee Range of Motion (ROM): Measured with a universal goniometer as per Al Mahmood et al. (2022). For participants with bilateral OA, the more symptomatic knee (higher baseline VAS) was evaluated for ROM and pain.

*Functional Status:* Assessed with the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), which has high internal consistency (Cronbach α > 0.9) and construct validity (Collins et al., 2011).

Inflammatory Biomarker**:** Serum IL-6 levels measured via ELISA (Frontiers standard protocol); this marker shows moderate test–retest reliability in OA (ICC ≈ 0.88) (Xie et al., 2023).

*Quality of Life:* Evaluated using the WHOQOL-BREF, which demonstrates excellent internal consistency (α = 0.84–0.93) and cross-cultural validity.

*Gait Parameters:* Step and stride length via footprint method (Joshi et al., 2018); the procedure has shown strong intra-rater reliability (ICC = 0.95).

**2.5 Statistical Analysis**

Normality was tested using the Shapiro–Wilk test. Within-group differences were assessed with paired t-tests, and between-group comparisons of change scores (Δ = Post – Pre) were made using independent t-tests. A significance level of $p < 0.05$ was considered statistically significant.

Primary analyses followed the intention-to-treat (ITT) principle (n=30). Missing post-intervention values for dropouts were imputed using last observation carried forward (LOCF). Per-protocol analyses were conducted on completers (PLWD n=13; CLWD n=14). All analyses were performed using SPSS v25.0 (IBM Corp., Armonk, NY, USA).

## 3. RESULTS

Thirty participants with grade II–III knee osteoarthritis were randomized into Group 1 (PLWD, n=15) and Group 2 (CLWD, n=15). Baseline demographic and anthropometric characteristics were comparable between the two groups, with no significant differences observed ($p > 0.05$) (Table 1). The mean age of the cohort was 66.0 ± 3.6 years, mean BMI was 34.6 ± 2.3 kg/m², and gender distribution was similar (Group 1: 7 males/8 females; Group 2: 8 males/7 females). During the 8-week intervention, two participants from the PLWD group and one participant from the CLWD group withdrew due to personal reasons and non-adherence. Thus, 13 participants in the PLWD group and 14 in the CLWD group completed the study (Figure 1). Baseline demographic and anthropometric characteristics were comparable between the two groups ($p > 0.05$) (Table 1). No adverse events such as burns, discomfort, or dizziness were reported during or after any treatment session in either group. All participants tolerated the interventions well.

Both groups demonstrated significant reductions in pain intensity as measured by VAS after 8 weeks ($p < 0.05$). However, CLWD produced a greater reduction compared with PLWD (Δ -5.70 ± 0.7 vs Δ -4.64 ± 0.8; $p < 0.05$) (Table 2).

Improvements in knee ROM were also significant in both groups, but the gains were larger in CLWD for both flexion (+18.0° ± 4.2 vs +11.0° ± 4.0; $p < 0.05$) and extension (+6.0° ± 1.2 vs +3.8° ± 1.1; $p < 0.05$) (Table 2).

Functional outcomes assessed by WOMAC subscales showed significant improvements across pain, stiffness, and physical function domains in both groups. Between-group analysis revealed that CLWD achieved greater reductions in WOMAC pain (Δ -9.8 ± 1.5 vs -7.9 ± 1.6; $p < 0.05$), stiffness (Δ -3.1 ± 0.8 vs -2.2 ± 0.7; $p < 0.05$), and physical function disability (Δ -26.8 ± 3.0 vs -21.9 ± 3.1; $p < 0.05$) (Table 2).

Quality of life, measured using WHOQOL-BREF, improved significantly in all domains. The CLWD group demonstrated larger gains compared with PLWD, including physical health (Δ +30.1 ± 5.0 vs +21.6 ± 4.8; $p < 0.05$), psychological (Δ +26.4 ± 4.9 vs +20.0 ± 4.6; $p < 0.05$), social (Δ +22.2 ± 4.3 vs +17.3 ± 4.1; $p < 0.05$), and environmental domains (Δ +24.6 ± 4.8 vs +18.5 ± 4.2; $p < 0.05$) (Table 2).

Serum IL-6 levels decreased significantly in both groups after intervention, with a greater reduction observed in CLWD (Δ -3.42 ± 0.6) compared with PLWD (Δ -2.05 ± 0.5; $p < 0.05$) (Table 2).

Gait analysis revealed significant improvements in step and stride length bilaterally in both groups. Again, CLWD produced greater improvements compared with PLWD. For step length, CLWD increased right and left sides by Δ +10.5 ± 1.8 cm and Δ +10.5 ± 2.7 cm, respectively, versus PLWD gains of Δ +6.6 ± 2.1 cm and Δ +6.9 ± 1.7 cm ($p < 0.05$). For stride length, CLWD showed right and left improvements of Δ +19.6 ± 2.4 cm and Δ +19.1 ± 2.6 cm, respectively, compared with PLWD increases of Δ +14.5 ± 2.8 cm and Δ +13.6 ± 3.5 cm ($p < 0.05$) (Table 2).

Normality assumptions were satisfied (Shapiro–Wilk $p > 0.05$ for most variables). Tables 1 and 2 and Figures 1–4 present detailed demographic, clinical, and outcome values.

**Table 1**. Baseline demographic and anthropometric characteristics of participants with knee osteoarthritis treated using pulsed long-wave diathermy (PLWD) and continuous long-wave diathermy (CLWD). Values are presented as mean ± standard deviation (SD) or number (n). No significant differences were observed between groups at baseline ($p > 0.05$).

| Variable | Group 1 (PLWD) | Group 2 (CLWD) | p-value |
|---|---|---|---|
| Age (years) | 65.8 ± 3.5 | 66.2 ± 3.7 | 0.71 |
| Weight (kg) | 73.8 ± 4.2 | 74.9 ± 4.4 | 0.62 |
| Height (cm) | 146.3 ± 5.1 | 147.0 ± 4.9 | O.68 |
| BMI (kg/m²) | 34.5 ± 2.2 | 34.9 ± 2.3 | 0.59 |
| Gender (M/F) | 7 / 8 | 8 / 7 | - |

Natural Resources for Human Health
eISSN: 2583-1194

**Table 2**. Mean pre–post changes (Δ = Post – Pre) in clinical, functional, quality of life, biomarker, and gait outcomes following 8 weeks of intervention with pulsed long-wave diathermy (PLWD) and continuous long-wave diathermy (CLWD). Values are expressed as mean ± SD. Negative Δ values indicate reductions (pain, stiffness, IL-6), while positive Δ values indicate improvements (ROM, WHOQOL, step/stride length). Between-group comparisons were analyzed using independent t-tests (*$p < 0.05$).

| Outcome | Group 1 (PLWD) | Group 2 (CLWD) | p-value |
|---|---|---|---|
| VAS (0–10) | Δ -4.64 ± 0.8 | Δ -5.70 ± 0.7 | <0.05 |
| Knee Flexion (°) | Δ +11.0 ± 4.0 | Δ +18.0 ± 4.2 | <0.05 |
| Knee Extension (°) | Δ +3.8 ± 1.1 | Δ +6.0 ± 1.2 | <0.05 |
| WOMAC Pain | Δ -7.9 ± 1.6 | Δ -9.8 ± 1.5 | <0.05 |
| WOMAC Stiffness | Δ -2.2 ± 0.7 | Δ -3.1 ± 0.8 | <0.05 |
| WOMAC Physical Function | Δ -21.9 ± 3.1 | Δ -26.8 ± 3.0 | <0.05 |
| WHOQOL Physical | Δ +21.6 ± 4.8 | Δ +30.1 ± 5.0 | <0.05 |
| WHOQOL Psychological | Δ +20.0 ± 4.6 | Δ +26.4 ± 4.9 | <0.05 |
| WHOQOL Social | Δ +17.3 ± 4.1 | Δ +22.2 ± 4.3 | <0.05 |
| WHOQOL Environmental | Δ +18.5 ± 4.2 | Δ +24.6 ± 4.8 | <0.05 |
| IL-6 (pg/mL) | Δ -2.05 ± 0.5 | Δ -3.42 ± 0.6 | <0.05 |
| Step Length Right (cm) | Δ +6.6 ± 2.1 | Δ +10.5 ± 1.8 | <0.05 |
| Step Length Left (cm) | Δ +6.9 ± 1.7 | Δ +10.5 ± 2.7 | <0.05 |
| Stride Length Right (cm) | Δ +14.5 ± 2.8 | Δ +19.6 ± 2.4 | <0.05 |
| Stride Length Left (cm) | Δ +13.6 ± 3.5 | Δ +19.1 ± 2.6 | <0.05 |

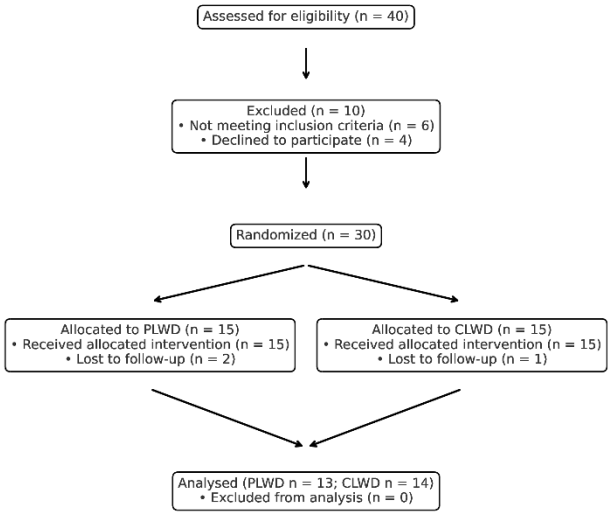


Figure 1. CONSORT flow diagram showing participant enrollment, randomization, allocation, follow-up, and analysis in pulsed (PLWD) and continuous (CLWD) long-wave diathermy groups.

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eISSN: 2583-1194

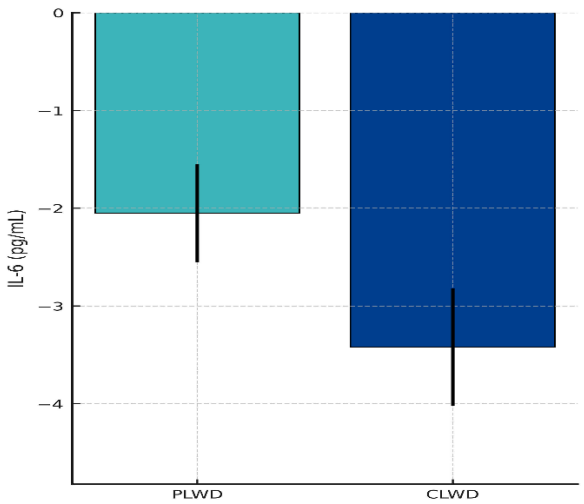


**Figure 2.**Graph showing the Inflammatory Biomarker in both groups

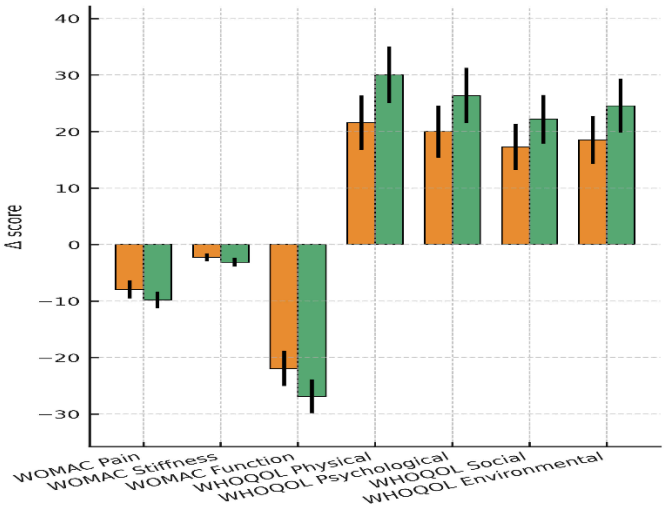


**Figure 3.** Graph showing functional status and quality of life in both the groups

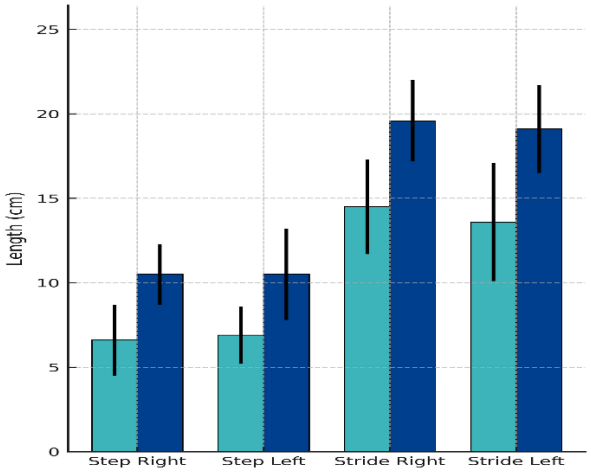


**Figure 4.** Graph showing changes in Gait parameters in both the groups

## 4. DISCUSSION

This randomized pilot trial demonstrated that continuous long-wave diathermy (CLWD) produced greater clinical and physiological benefits than pulsed long-wave diathermy (PLWD) in patients with moderate knee osteoarthritis (knee OA). Both modalities, when combined with conventional physiotherapy, significantly improved pain, range of motion, function, quality of life, and gait parameters. However, the magnitude of change was consistently higher in the CLWD group, particularly for IL-6 reduction.

The present findings corroborate prior studies on short-wave diathermy reporting superior outcomes with continuous energy delivery (Onigbinde et al., 2013; Ozen et al., 2019; Akyol et al., 2010). Jia et al. (2022) observed that continuous ultrasound-based stimulation modulated inflammatory cytokines more effectively than pulsed modes—an observation that parallels our IL-6 results. The sustained thermal effect of CLWD likely augments local circulation and oxygenation, accelerating clearance of pro-inflammatory mediators.

From a comparative-physiology perspective, the mode of energy application mirrors the difference between continuous and intermittent exercise stimuli. Continuous endurance training produces sustained hemodynamic stress and angiogenic signaling, while intermittent exercise elicits episodic cellular responses (Hunter & Bierma-Zeinstra, 2019). Allen et al. (2022) likewise reported distinct hematological patterns between continuous running and cycling. Similarly, uninterrupted thermal exposure from CLWD may enhance collagen extensibility, synovial fluid viscosity, and metabolic recovery—thereby yielding the superior functional and biomarker outcomes observed.

Mechanistically, continuous heating can improve tissue compliance and microvascular perfusion, leading to decreased stiffness and pain. These physiological changes support the observed improvements in WOMAC and WHOQOL-BREF domains. Additionally, IL-6 reduction underscores the potential anti-inflammatory role of thermotherapy in chronic degenerative conditions (Anand et al., 2025b; Xie et al., 2023).

Strengths and Limitations: This study incorporated both subjective (pain, QoL) and objective (biomarker, gait) outcomes and applied an intention-to-treat analysis. Limitations include its small sample size, single-center design, and short follow-up. Future multicenter randomized trials with long-term evaluation and multiple biomarker profiling (IL-1β, TNF-α, MMPs) are warranted.

Clinical implications: Integrating CLWD into standard physiotherapy protocols may provide a safe, non-pharmacological option for patients with moderate knee OA. Its ability to concurrently reduce inflammatory burden and enhance mobility may contribute to comprehensive rehabilitation outcomes.

## 5. CONCLUSION

Continuous long-wave diathermy (CLWD), when integrated into conventional physiotherapy, produced superior improvements in pain, mobility, functional performance, quality of life, inflammatory modulation, and gait parameters compared with pulsed long-wave diathermy (PLWD) in patients with grade II–III knee OA. These pilot findings highlight the clinical promise of CLWD as an effective, non-pharmacological adjunct in OA rehabilitation and warrant confirmation through larger multicenter randomized trials.

**Conflict of Interest:** The authors declare no conflict of interest.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgments: The authors gratefully acknowledge Amar Amolak Charitable Trust Laboratory, Noida, for laboratory support and AID Plus Physiotherapy Center for intervention support.

Authors' Contributions:
Conceptualization, BA, PK, and CK;
Methodology, BA and PK;
Formal analysis, BA and PK;
Investigation, BA;
Resources, PK and CK;

Data curation, BA;
Writing – original draft preparation, BA;
Writing – review and editing, PK and CK;
Visualization, BA and PK;
Supervision, PK and CK.
All authors have read and approved the final manuscript.

Data Availability: The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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