

Multimodal Electrophysical Therapy Over Eccentric Exercise Monotherapy for De Quervain's Tenosynovitis: A Two-Arm Randomized Trial.

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ABSTRACT

Background: De Quervain's tenosynovitis is a debilitating upper-limb tendinopathy. While eccentric exercise is a standard mechanical intervention, the clinical value of combining it with multimodal electrophysical modalities remains unclear.

Objective: To evaluate the additive therapeutic efficacy of combining 980 nm near-infrared Low-Level Laser Therapy (LLLT) and pulsed 3 MHz Ultrasound Therapy (UST) with a standardized eccentric exercise protocol for subacute-to-chronic De Quervain's tenosynovitis.

Methods: This parallel-group randomized controlled trial enrolled 50 participants (aged 18–60 years) with symptoms persisting for ≥ 4 weeks. Participants were randomly allocated to Group 1 (Experimental: Eccentric Exercise + LLLT [980 nm, 200 mW, 6 J/cm²] + UST [3 MHz, pulsed 1:4, 1.2 W/cm²]; n=25) or Group 2 (Active Control: Eccentric Exercise Monotherapy; n=25). Interventions were administered 3 days per week for 4 consecutive weeks. Primary and secondary clinical outcomes were pain intensity (Visual Analog Scale [VAS]) and upper-limb functional status (Disabilities of the Arm, Shoulder, and Hand [DASH] questionnaire), mapped at Baseline (Week 0) and Post-Intervention (Week 4).

Results: Independent-samples t-tests confirmed robust baseline group homogeneity for both VAS ($p=0.525$) and DASH ($p=0.591$) scores. After 4 weeks, paired t-tests showed highly significant intra-group improvements across both cohorts ($p<0.001$). However, post-intervention inter-group analysis using independent t-tests revealed a statistically significant superior recovery in Group 1 over Group 2, demonstrating significantly greater reduction in localized pain intensity ($t_{(48)}=-9.657$, $p<0.001$) and residual functional disability ($t_{(48)}=-11.724$, $p<0.001$).

Conclusion: Integrating 980 nm infrared photobiomodulation and pulsed 3 MHz ultrasound therapy with a standardized eccentric exercise regimen accelerates pain resolution and functional independence, providing clear therapeutic superiority over exercise monotherapy.

Keywords: De Quervain's Tenosynovitis, Eccentric Exercise, Low-Level Laser Therapy, Therapeutic Ultrasound, Visual Analog Scale, DASH Questionnaire.

1. INTRODUCTION

De Quervain's disease is a localized stenosing tendinopathy affecting the first dorsal extensor compartment of the wrist. The underlying mechanism involves chronic mechanical friction and structural overloading of two distinct tendons: the abductor pollicis longus (APL) and the extensor pollicis brevis (EPB). Although historically classified as an inflammatory disorder, histopathological data demonstrates that the condition is non-inflammatory. Instead, it is characterized by myxoid degeneration and fibrous thickening of the extensor retinaculum, accompanied by the accumulation of tissue mucopolysaccharides. This localized retinacular hypertrophy narrows the osteofibrous canal, inducing compartment compression and compromising the smooth gliding action of the tendons over the radial styloid process. [1].

Continuous, long-term immobilization via rigid thumb spica splinting yields poor standalone therapeutic outcomes for De Quervain's disease [2]. Prolonged static casting routinely causes localized muscle weakness, joint contractures, and adverse neuroplastic alterations in the affected forearm musculature [3]. Furthermore, unbroken immobilization fails to provide long-term symptomatic relief, frequently triggering disuse muscle atrophy that delays overall functional rehabilitation [2, 3]. Contemporary clinical guidelines, advocate against full-time, rigid restriction [3]. Instead, current strategies emphasize early, controlled motion to facilitate tendon excursion and maintain functional upper-extremity strength [2, 3]. Transitioning from static splinting to progressive, movement-based rehabilitation remains essential for successful long-term recovery [4, 5].

Progressive mechanical loading via eccentric exercise is widely integrated into tendinopathy rehabilitation to expand tendon load capacity, optimize muscle–tendon function, and heighten mechanical stress tolerance. Concurrently, photobiomodulation therapy (PBM)—historically termed low-level laser therapy (LLLT)—is utilized to modulate localized nociception and accelerate cellular tissue recovery. Clinical evidence indicates that combining PBM with targeted therapeutic exercise yields synergistic advantages in tendinopathy management, despite substantial heterogeneity in existing literature regarding wavelength, energy density, and dosing schedules.[6,7]. For De Quervain's disease specifically, clinical trials evaluating LLLT and therapeutic ultrasound as standalone conservative interventions demonstrate notable reductions in pain indices and significant functional improvement.[8,9]. These data strongly validate the therapeutic potential of pairing active mechanical protocols with adjunctive physical modalities.

A multi-tiered regimen combining eccentric loading, low-level infra red laser application, and therapeutic ultrasound may deliver complementary benefits by targeting distinct pathways of tissue recovery. Mechanically, eccentric exercise applies a progressive, adaptive stimulus to the compromised tendon architecture. Biologically, photobiomodulation prompts cellular-level tissue repair and analgesic responses, while ultrasound supplies local micro-mechanical and thermal actions to the deep tissues.[6,8,10]. Although previous literature documents the individual benefits of laser or ultrasound application in De Quervain's cases [9-11], robust empirical data regarding the clinical efficacy of embedding these adjuncts into a standardized, eccentric-focused framework remains scarce. Consequently, the present study aims to evaluate whether integrating 980-nm infrared laser irradiation and therapeutic ultrasound with a foundation of eccentric exercise produces superior reductions in pain intensity and upper-limb functional disability compared to eccentric exercise alone.

2. MATERIALS & METHODS

This study was a prospective, two-arm parallel-group randomized controlled trial executed over a 4-week intervention window. All participants provided written, informed consent prior to clinical screening and group allocation.

Participants were randomly assigned (1:1 allocation ratio) into one of two treatment groups:

Experimental Group (Group 1): Combined Multimodal Therapy consisting of Low-Level Laser Therapy (LLLT), Pulsed Ultrasound Therapy (UST), and a Standardized Eccentric Exercise Protocol.

Active Control Group (Group 2): Monotherapy consisting solely of the Standardized Eccentric Exercise Protocol.

Both cohorts underwent supervised clinical therapeutic sessions 3 days per week for 4 consecutive weeks, culminating in a total of 12 treatment sessions per participant.

Participant Screening and Selection Criteria

Inclusion Criteria

Potential candidates were systematically screened for eligibility based on the following precise objective markers:

- Presentation of unilateral De Quervain's tenosynovitis, clinically verified by a pathognomonic positive response to Finkelstein's diagnostic maneuver.
- A symptom duration persisting for more than 4 weeks prior to enrollment, confirming the resolution of hyper-acute tissue changes and entry into the subacute-to-chronic fibroblastic remodeling phase.
- A baseline Visual Analog Scale (VAS) score localized between 3/10 and 6/10 during active mechanical testing (thumb extension or abduction), representing moderate, non-debilitating clinical irritability.
- Adult male or female patients aged between 18 and 60 years.

Exclusion Criteria

To isolate the primary pathological variable, individuals presenting with any of the following confounding elements were excluded:

- Hyper-Acute Tenuous Inflammation – Visible regional erythema, localized palpable warmth, or macroscopic resting edema overlying the first dorsal compartment.
- Co-existing carpal tunnel syndrome, cervical radiculopathy (C6-C7), intersection syndrome, thumb carpometacarpal osteoarthritis, or a history of fractures/surgeries to the ipsilateral wrist or hand.
- Localized corticosteroid infiltration within the preceding 3 months, or any structured upper-limb physical therapy regimen within the past 4 weeks.
- Diagnosed metabolic or autoimmune diseases that alter collagen synthesis or tissue healing kinetics, including Diabetes Mellitus, Rheumatoid Arthritis, or Gout.
- Absolute Modality Contraindications – Local cutaneous lesions, regional malignancy, cardiac pacemakers, or active pregnancy.

Standardized Eccentric Exercise Protocol (Both Cohorts)

To deliver precise mechanical loading to the Abductor Pollicis Longus (APL) and Extensor Pollicis Brevis (EPB) complex while eliminating shear-induced friction associated with active concentric shortening within the stenosed retinaculum, both groups executed an identical eccentric ulnar deviation regimen.[12] Anatomical Stabilization: Participants sat upright with the treated forearm fully supported on a therapy table in a neutral mid-pronated position. The wrist joint and manus extended past the edge of the supporting surface to facilitate unconstrained mechanical excursion through the radial-ulnar plane.

The 4-Step Kinematic Cycle:

- 1) Passive Phase: The participant utilized their contralateral, unaffected hand to passively lift a standardized free-weight into end-range wrist radial deviation, achieving zero active concentric contraction in the targeted forearm compartment.
- 2) Load Transfer: At terminal radial deviation, contralateral support was disengaged, transferring the entire vertical load purely to the targeted wrist musculature.
- 3) Controlled Eccentric Lengthening: The participant executed a controlled, decelerated deceleration of the load into full ulnar deviation over a strict 4-second duration, monitored via an audible digital metronome (60 BPM).
- 4) De-loading and Reset. At terminal ulnar range, the contralateral hand re-engaged to take the load and passively return the wrist to the starting baseline.

Dosage Volumetrics: Both cohorts performed 3 sets of 15 repetitions, partitioned by a standardized 60-second inter-set rest interval.

Symptom-Modulated Load Progression: The initial mechanical load was established at a conservative baseline (0.5 kg to 1.0 kg). Upward load progression (+0.5 kg) was permitted in subsequent sessions only if the participant maintained an exertional score of less than or equal to 3/10 on the Visual Analogue Scale (VAS) without inducing a latent symptom flare-up exceeding 24 hours post-exercise [12]. If baseline pre-exercise irritability exceeded an VAS of 4/10, external resistance was omitted, and the protocol was modulated to zero external load (bodyweight of the hand only) for that session to protect the tendon sheath. Electrophysical Interventions (Group 1 Only)

For the multi-modal experimental cohort, electrophysical modalities were sequentially administered directly prior to the mechanical loading protocol to optimize immediate localized analgesia, reduce interstitial fluid pressures, and lower mechanical nociceptor activation.

Low-Level Laser Therapy (LLLT) Photobiomodulation

- Laser Architecture: Gallium Arsenide (GaAs) semiconductor diode infrared laser emitter.
- Spectral Wavelength: 980 nm (Near-Infrared spectrum).
- Power Delivery: Continuous-wave output fixed at 200 mW (0.200 W).
- Application Interface: Stationary, firm contact method deployed perpendicular to the skin surface to minimize optical backscattering.

- Anatomical Targets: 3 standardized anatomical coordinates directly overlying the path of the Abductor Pollicis Longus (APL) and Extensor Pollicis Brevis (EPB) tendons within the first dorsal compartment.
- Dosimetry Density: 6.0 J/cm² per coordinate point.
- Temporal Exposure: 30 seconds per point using a calibrated probe aperture with a nominal beam spot size of 1.0 cm², yielding a total active exposure time of 90 seconds per therapeutic session.

Therapeutic Ultrasound Therapy (UST)

- Acoustic Frequency: 3 MHz targeting the superficial boundaries of the radial styloid process.
- Temporal Waveform: Pulsed mode calibrated to a 1:4 duty cycle (20% active temporal output).
- Application Interface: Continuous translational movement in slow, overlapping concentric patterns using water-soluble coupling medium as an acoustic bridge.
- Output Intensity: Fixed at 1.2 W/cm² Spatial Average Temporal Average (SATA).
- Temporal Duration: Exactly 5 minutes per treatment session.

Clinical Outcome Metrics

Objective clinical measurements were acquired at two key intervals: Baseline (Week 0) and immediately Post-Intervention (Week 4).

- Primary Outcome (Nociceptive Intensity): Quantified via a 100-mm visual analog scale (VAS), measuring the patient's subjective pain perception during a standard active thumb excursion test.
- Secondary Functional Metric: Evaluated through the validated Disabilities of the Arm, Shoulder, and Hand (DASH) patient-reported outcome tool to track upper-extremity functional limitations

Statistical Analysis

Statistical mapping was performed using SPSS (Version 26.0). Continuous variables (VAS & DASH scores) were expressed as Mean $\pm$ Standard Deviation (SD). Data normality was verified using the Shapiro-Wilk test. A paired-samples t-test was utilized to evaluate intra-group (within-group) changes in pain intensity from Baseline (Week 0) to Post-Intervention (Week 4). An independent-samples (unpaired) t-test was conducted to analyze inter-group (between-group) differences at baseline to confirm homogeneity, as well as to compare post-intervention mean scores between the two cohorts. The level of significance was set a priori at ($p < 0.05$).

The calculated statistical metrics are summarized in the table below.

Table 1. Comparison of pre- and post-intervention Visual Analog Scale (VAS) scores between the experimental group (n=25) and the active control group (n=25) using paired and independent-samples t-tests.

Pain Intensity Metric (VAS 0–10)	Group1: Experimental (Eccentric + LLLT + UST) (n = 25)	Active Control (Eccentric Only) (n = 25)	Inter-Group Analysis (Unpaired t-test)
Baseline (Week 0)	5.32 ± 0.56	5.22 ± 0.57	t = 0.641, p = 0.525 (NS)
Post-Intervention (Week 4)	1.90 ± 0.51	3.21 ± 0.44	t = -9.657, p < 0.001 (Highly Sig.)
Intra-Group Change (Paired t-test)	t = 22.597, p < 0.001	t = 15.992, p < 0.001	Experimental cohort yields superior pain resolution

Pain Intensity Evaluation (Visual Analog Scale)

Baseline Homogeneity

An independent -samples t-test demonstrated zero statistically significant difference in baseline VAS scores between Group 1 (5.32 ± 0.56) and Group 2 (5.22 ± 0.57) prior to the intervention window ($t(48) = 0.641$, $p = 0.525$). This indicates robust pre-treatment baseline matching across both allocations.

Intra-Group Treatment Efficacy

Experimental Group (Group 1): A paired-samples t-test demonstrated a statistically significant reduction in pain intensity following the 4-week protocol. Mean scores decreased by 64.3%, dropping from (5.32 ± 0.56) at baseline to 1.90 ± 0.51 post-intervention ($t(24) = 22.597$, $p < 0.001$).

Active Control Group (Group 2): A paired-samples t-test also revealed a significant post-treatment pain reduction. Mean scores decreased by 38.5%, moving from 5.22 ± 0.57 to 3.21 ± 0.44 at Week 4 ($t(24) = 15.992$, $p < 0.001$).

Inter-Group Superiority

At the 4-week post-intervention milestone, an independent-samples t- test revealed a highly significant between-group difference in residual pain scores ($t(48) = -9.657$, $p < 0.001$). Group 1 achieved a significantly greater therapeutic reduction in pain intensity compared to Group 2, with a mean difference of 1.31 points on the VAS scale.

This statistical confirmation satisfies the $p < 0.05$ clinical significance threshold. It confirms the hypothesis that combining 980 nm infrared laser and pulsed 3 MHz ultrasound with eccentric exercises provides superior clinical outcomes compared to standard eccentric exercise monotherapy.

Table 2. Comparison of baseline and post-intervention Disabilities of the Arm, Shoulder, and Hand (DASH) functional scores between the experimental group (n=25) and the active control group (n=25) using paired and independent-samples t-tests.

Functional Outcome (DASH, 0–100)	Experimental Group (Group 1) (Eccentric + LLLT + UST) (n = 25)	Active Control Group (Group 2) (Eccentric Only) (n = 25)	Inter-Group Comparative Statistics (t-test)
Baseline (Week 0)	44.60 ± 4.80	43.84 ± 5.12	t= 0.541, p = 0.591 (NS)
Post-Intervention (Week 4)	14.20 ± 3.14	26.56 ± 4.25	t = -11.724, p < 0.001 (Highly Sig.)
Intra-Group Statistics (Paired t-test)	t = 29.584, p < 0.001	t = 18.239, p < 0.001	Experimental cohort yields greater functional independence.

Functional Status Evaluation (DASH Questionnaire)

Baseline Homogeneity

Analysis of pre-intervention functional disability via the DASH questionnaire confirmed no statistically significant variance between Group 1 (44.60 ± 4.80) and Group 2 (43.84 ± 5.12) at Week 0 (t(48) = 0.541), p = 0.591. Both cohorts exhibited comparable baseline levels of upper-limb functional impairment.

Intra-Group Functional Efficacy

Experimental Group (Group 1): A paired-samples t-test demonstrated a substantial, statistically significant improvement in upper-limb function over the 4-week protocol. The mean DASH score decreased by 68.2%, dropping from a baseline of 44.60 ± 4.80 to 14.20 ± 3.14 post-intervention (t = 29.584, p < 0.001)

Active Control Group (Group 2): A paired-samples t-test also revealed a significant reduction in functional limitations. The mean cohort score decreased by 39.4%, shifting from 43.84 ± 5.12 at baseline to 26.56 ± 4.25 Week 4 (t = 18.239, p < 0.001)

Intergroup Functional Superiority

At the 4-week post-intervention milestone, an independent-samples t -test demonstrated a highly significant between-group difference in residual functional disability (t(48) = -11.724, p < 0.001). Group

1 achieved a profoundly lower mean DASH score compared to Group 2, representing a statistically superior net functional benefit (mean difference of 12.36 points).

This outcome falls well below the $p < 0.05$ alpha threshold, confirming that the integration of multimodal electrophysical agents (980 nm LLLT and pulsed 3 MHz UST) with eccentric training yields greater functional independence in activities of daily living than exercise therapy alone.

3. RESULT

An independent-samples t-test confirmed robust baseline homogeneity between groups, demonstrating zero statistically significant variance in pre-treatment scores for either the Visual Analog Scale $t(48) = 0.641$, $p = 0.525$ or the Disabilities of the Arm, Shoulder, and Hand questionnaire $t(48) = 0.541$, $p = 0.591$. Following the 4-week intervention window, paired-samples t-tests revealed that both cohorts achieved highly significant intra-group improvements ($p < 0.001$), marked by significant longitudinal reductions in localized pain intensity and upper-limb functional disability.

Post-intervention inter-group analysis using independent-samples t-tests established clear therapeutic superiority for the multimodal experimental group over the active control arm at Week 4. Group 1 achieved a significantly greater magnitude of pain resolution $t(48) = -9.657$, $p < 0.001$ and demonstrated a statistically superior reduction in residual functional limitations $t(48) = -11.724$, $p < 0.001$ compared to Group 2. These findings satisfy the $p < 0.05$ clinical significance threshold, confirming that integrating 980 nm infrared laser and pulsed 3 MHz ultrasound with eccentric exercises accelerates recovery compared to exercise monotherapy.

4. DISCUSSION

This randomized controlled trial demonstrated that while standard eccentric exercise monotherapy yields definitive clinical improvements, combining an eccentric protocol with 980 nm low-level laser therapy (LLLT) and pulsed 3 MHz ultrasound therapy (UST) delivers highly superior pain resolution and functional recovery in subacute-to-chronic De Quervain's tenosynovitis.

The significant intra-group improvements observed in both cohorts validate the biomechanical utility of eccentric training for managing stenosing tenosynovitis, supporting prior clinical assertions regarding mechanical tendon loading. By executing a passive-assisted radial deviation phase, the protocol successfully bypassed active, concentric shortening of the Abductor Pollicis Longus (APL) and Extensor Pollicis Brevis (EPB) muscles. This layout minimizes muscle-tendon friction and shear stress against the thickened extensor retinaculum. Subsequent controlled lengthening during the 4-second eccentric ulnar deviation phase delivers a localized tensile load. This mechanical strain stimulates tenocyte mechanotransduction, upregulates protein synthesis, and promotes the structural reorganization of disorganized collagen bundles within the extracellular matrix, which is highly consistent with established models of tendon remodeling under load.[12].

The definitive statistical superiority achieved by Group 1 reflects the synergistic, multimodal integration of physical loading and targeted electrophysical agents. Introducing continuous-wave 980 nm infrared

LLLT immediately prior to mechanical exercise provides deep photobiomodulatory penetration to the deeper layers of the first dorsal compartment. At a cellular level, photon absorption by cytochrome c oxidase within the mitochondrial respiratory chain upregulates adenosine triphosphate (ATP) synthesis, accelerates cellular proliferation, and modulates the localized inflammatory cascade by suppressing pro-inflammatory cytokines. Furthermore, 980 nm irradiation alters nociceptive neural transmission, increasing the activation threshold of localized free nerve endings to provide immediate analgesia.[13].

This anti-inflammatory and analgesic state was augmented by the non-thermal mechanical configurations of the pulsed 3 MHz ultrasound protocol. Utilizing a 20% duty cycle entirely eliminated localized acoustic thermal accumulation, preventing secondary inflammatory aggravation of the irritated fibro-osseous canal. The translational acoustic waves induce high-frequency micro-streaming and stable cavitation within the interstitial fluids, which increases cell membrane permeability, upregulates calcium ion influx, and stimulates macrophage and fibroblast activity [14].

Consequently, local microcirculation is optimized, accelerated interstitial fluid reabsorption reduces local edema, and type-I collagen deposition within the sheath is enhanced. By attenuating localized biochemical inflammation and nociceptor sensitivity prior to physical movement, these modalities expanded the participant's pain-free range of motion, allowing safe, early mechanical loading under the eccentric protocol, producing superior reductions in overall clinical disability scores.[13].

Study Limitations

The primary limitations of this investigation comprise the evaluation of short-term therapeutic outcomes restricted to a 4-week intervention window and the absence of a long-term post-discharge follow-up to ascertain structural recurrence rates. Additionally, objective diagnostic imaging modalities, such as high-resolution musculoskeletal ultrasound to quantify structural changes in tendon sheath thickness, were not utilized. Future investigations should incorporate long-term longitudinal monitoring combined with sonographic structural assessments.

5. CONCLUSION.

A 4-week intervention comprising a standardized eccentric ulnar deviation protocol combined with continuous-wave 980 nm low-level laser therapy and pulsed 3 MHz ultrasound therapy is highly effective and statistically superior to eccentric exercise monotherapy in treating subacute-to-chronic De Quervain's tenosynovitis. The multimodal approach accelerates pain resolution and restores upper-limb functional independence. Clinicians can confidently integrate these electrophysical agents as a standard pre-exercise workflow to optimize mechanical loading tolerance and accelerate patient recovery.

Declaration by Authors

Ethical Approval: Approved

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