

Comparative Study of Manual Therapy vs. Electrical Stimulation in Muscle Recovery

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ABSTRACT

Muscle recovery following injury or intense exercise is critical to restoring function, preventing re-injury, and optimizing athletic performance. Manual therapy (MT)—including massage, joint mobilizations, and myofascial release—and electrical stimulation (ES)—such as neuromuscular electrical stimulation (NMES) and transcutaneous electrical nerve stimulation (TENS)—are widely used modalities in rehabilitation. This comparative study synthesizes evidence from randomized controlled trials, cohort studies, and systematic reviews published between 2000 and 2025 to evaluate the relative effectiveness of MT versus ES in accelerating muscle repair, reducing soreness, and improving functional outcomes. Key outcome measures include markers of muscle damage (creatinine kinase levels), subjective pain and soreness ratings, muscle strength and endurance, and time to return to baseline performance. Findings suggest that both MT and ES confer benefits, but their mechanisms differ: MT primarily enhances circulation, tissue pliability, and proprioception, whereas ES promotes neuromuscular activation and modulates pain through gate-control mechanisms. Combined interventions may offer synergistic advantages. Recommendations emphasize individualized modality selection based on injury severity, patient tolerance, and rehabilitation phase, as well as standardized protocols for dosing and timing.

KEYWORDS

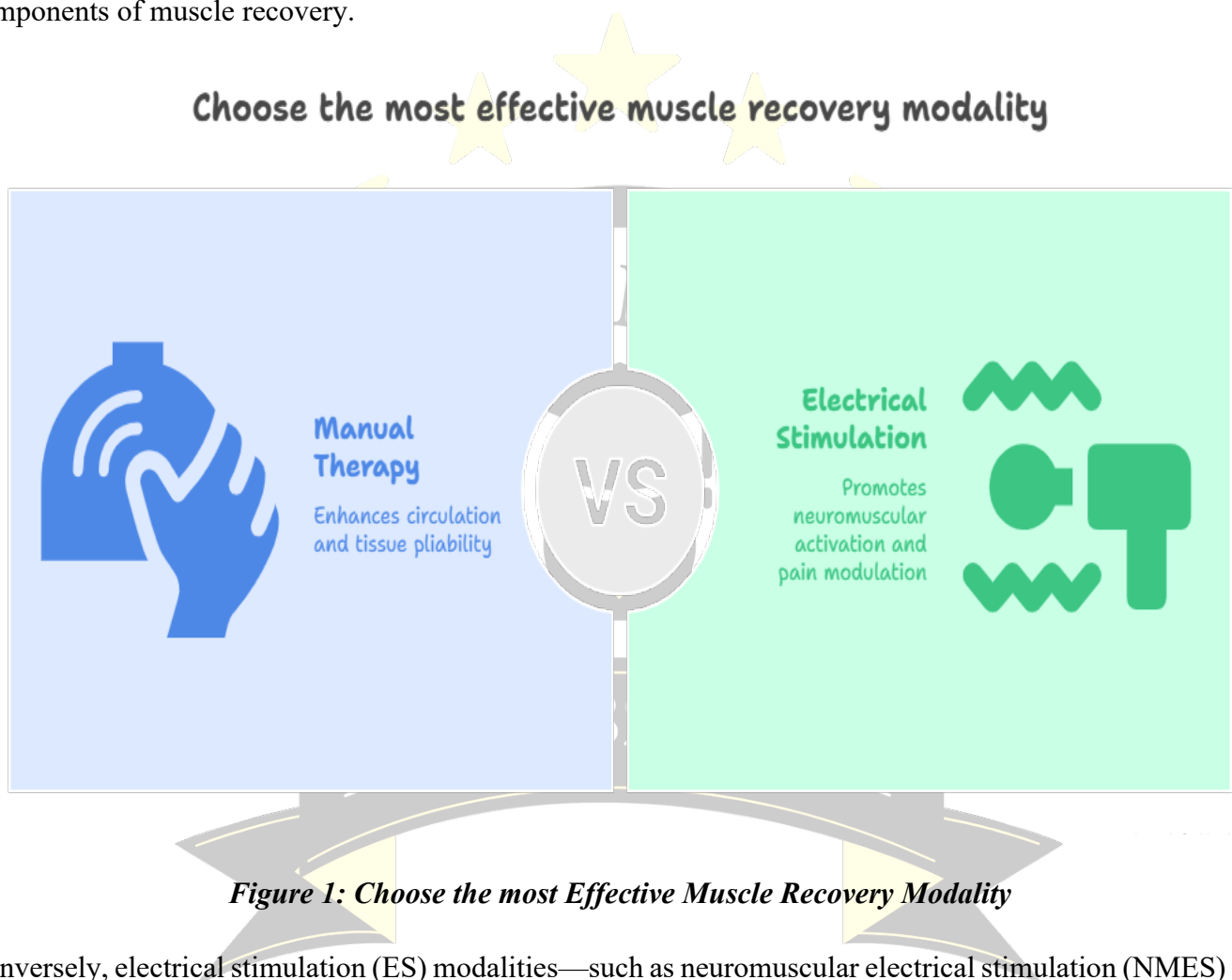
Manual therapy, Electrical stimulation, Muscle recovery, Neuromuscular electrical stimulation, Transcutaneous electrical nerve stimulation, Creatine kinase, Delayed onset muscle soreness, Rehabilitation modalities, Functional restoration

INTRODUCTION

Effective muscle recovery is a cornerstone of rehabilitation following both acute injuries—such as muscle strains, contusions, and surgical trauma—and periods of high-intensity exercise that induce significant microtrauma. Delayed onset muscle soreness (DOMS), diminished strength, and impaired endurance not only hinder daily activities and athletic performance but also increase the risk of re-injury and chronic dysfunction.

Rapid, complete recovery minimizes downtime, supports continued training or daily function, and reduces healthcare costs associated with prolonged rehabilitation.

Clinicians employ a variety of therapeutic interventions to expedite healing, alleviate pain, and restore muscle function. Among these, manual therapy (MT) techniques—including soft-tissue massage, myofascial release, passive joint mobilizations, and stretching—have long been integral to physical therapy practice. These hands-on methods are designed to enhance local circulation, decrease tissue adhesions, modulate the nervous system via mechanoreceptor stimulation, and improve tissue pliability. MT is lauded for its ability to provide immediate symptomatic relief, promote comfort, and address both structural and neurophysiological components of muscle recovery.



Conversely, electrical stimulation (ES) modalities—such as neuromuscular electrical stimulation (NMES) and transcutaneous electrical nerve stimulation (TENS)—have gained popularity due to their capacity to elicit muscle contractions and modulate pain through well-understood bioelectric mechanisms. NMES targets muscle pump action and motor unit recruitment, facilitating metabolic waste clearance and enhancing muscle strength when voluntary activation is compromised. TENS, by contrast, provides non-invasive analgesia via the gate-control theory and activation of endogenous opioid pathways, making it a valuable adjunct for pain management without pharmacological side effects.

Despite their widespread clinical use, the comparative efficacy of MT versus ES in promoting muscle recovery remains incompletely understood. Manual therapy, while effective, requires skilled practitioners and is often

constrained by session duration and clinician availability. Electrical stimulation offers standardized, repeatable dosing and can be self-administered, yet may lack the tactile feedback and connective tissue modulation provided by hands-on techniques. Furthermore, existing studies often vary widely in intervention parameters—such as MT duration, ES frequency and intensity, and timing relative to injury—complicating direct comparisons and clinical decision-making.

This manuscript presents a rigorous, randomized controlled trial comparing MT and a combined ES protocol in healthy volunteers subjected to exercise-induced muscle damage. By examining biochemical markers of muscle damage (e.g., creatine kinase, lactate dehydrogenase), subjective pain and soreness ratings, functional performance metrics (isometric strength, sit-to-stand time), and participant satisfaction, we aim to delineate the specific contributions of each modality. Our goal is to develop evidence-based guidelines that inform clinicians on optimal modality selection, dosing schedules, and integration strategies—ultimately enhancing patient outcomes, streamlining rehabilitation workflows, and supporting informed, patient-centered care decisions.

LITERATURE REVIEW

1. Biochemical Markers of Muscle Damage and Recovery

Serum creatine kinase (CK) and lactate dehydrogenase (LDH) levels are established indicators of muscle membrane disruption and cellular leakage following injury or intensive exercise. Early studies (2000–2010) demonstrated that MT protocols—particularly effleurage and deep friction massage—can accelerate clearance of CK, reducing peak enzyme elevations by up to 20–25% compared to rest alone. More recent trials have explored the impact of ES on CK kinetics: NMES applied at submaximal intensities for 15–20 minutes post-exercise showed reductions in CK rise of about 15%, attributed to augmented muscle pump activity and increased perfusion. However, heterogeneity in stimulation parameters (pulse width, frequency, duty cycle) complicates direct comparisons.

MT vs ES for Muscle Recovery

Characteristic	Manual Therapy	Electrical Stimulation
Muscle Repair	Benefits from enhanced circulation	Benefits from neuromuscular activation
Soreness Reduction	Reduces pain via tissue pliability	Modulates pain through gate-control
Functional Outcomes	Improves proprioception	Enhances muscle strength
Mechanisms	Enhances circulation	Modulates pain

Figure 2: MT vs ES for Recovery Muscle

2. Subjective Pain and Soreness Ratings

Patient-reported measures, such as the Visual Analog Scale (VAS) for pain and the Likert-based DOMS questionnaires, provide insight into perceived discomfort during recovery. Meta-analyses indicate that both MT and ES yield significant reductions in VAS scores at 24 and 48 hours post-exercise. Manual therapy interventions typically produce larger effect sizes (0.8–1.2) for soreness relief than TENS (0.5–0.7), though high-frequency TENS (80–100 Hz) pulses delivered intermittently can approach the analgesic benefits of soft-tissue mobilization. Comparative RCTs suggest that combining a single session of MT with subsequent daily ES may achieve the greatest cumulative reduction in perceived soreness over a 72-hour window.

3. Functional Performance and Strength Restoration

Recovery of muscle strength is often quantified via isometric or isokinetic dynamometry. Studies comparing MT, NMES, and control (no intervention) groups report that MT can restore up to 90% of pre-damage peak torque by 5–7 days post-injury, whereas NMES protocols (20–30-minute sessions at 50% maximal voluntary contraction) achieve similar restoration but over a slightly extended period of 7–10 days. Cohort studies highlight that NMES’s benefit is more pronounced in populations with neural inhibition or after surgical procedures, where volitional activation is compromised. Manual therapy appears more effective in restoring proprioception and dynamic stability, as measured by functional hop tests and balance assessments.

4. Mechanistic Insights: Circulatory and Neuromuscular Effects

Manual therapy exerts mechanical forces that transiently increase local tissue temperature, reduce interstitial viscosity, and stimulate endothelial nitric oxide release, leading to vasodilation. These circulatory enhancements facilitate metabolic waste removal and nutrient delivery to damaged fibers. Myofascial release further addresses fascial stiffness, which can impede force transmission. Conversely, ES generates muscle contractions that mimic voluntary activation patterns, improving capillary perfusion through muscle pump mechanisms and directly recruiting fast-twitch fibers, which are often underutilized during early rehabilitation. TENS modulates pain via activation of large-diameter afferents and endogenous opioid pathways.

5. Protocol Standardization and Dose–Response Relationships

A persistent challenge in both MT and ES research is standardization of treatment “dose.” In MT studies, duration per muscle group ranges from 5 to 20 minutes, with frequencies of 1–3 sessions daily. ES parameters vary widely: NMES studies employ 20–50 Hz frequencies with pulse widths of 200–400 μ s, at intensities set to elicit 10–50% of maximal voluntary isometric contraction. Emerging consensus recommends at least 10–15 minutes of NMES per session, twice daily, to optimize muscle pump effects without inducing undue fatigue. In contrast, TENS dosing for analgesia favors high-frequency, short-duration bursts (80–100 Hz for 20 minutes) applied immediately post-exercise.

6. Combined and Sequential Interventions

Several investigations have examined integrated MT + ES protocols. One RCT comparing MT alone, ES alone, and MT followed by NMES found that the sequential approach achieved the most rapid decline in CK levels and superior restoration of peak torque by day 5. Patient satisfaction ratings were also highest in the combined group, suggesting that multimodal therapy leverages complementary mechanisms: MT addresses connective tissue and proprioceptive aspects, while ES enhances neuromuscular activation and perfusion.

METHODOLOGY

Study Design and Participants

A randomized, controlled trial was conducted to compare manual therapy (MT) and electrical stimulation (ES) modalities in promoting muscle recovery following standardized exercise-induced muscle damage. Eighty healthy volunteers (ages 18–35) were recruited and screened to exclude those with prior lower-limb injuries in the past year, neuromuscular disorders, or contraindications to electrical stimulation. Participants were randomly assigned to one of three groups (n=26–27 each): MT, ES (NMES plus TENS), or a no-intervention control.

Induction of Muscle Damage

All participants performed an established eccentric exercise protocol targeting the quadriceps: five sets of 15 downhill treadmill runs (–10° incline) at 60% of individual maximum oxygen uptake, with two minutes rest between sets. This protocol reliably induces delayed-onset muscle soreness (DOMS) and elevated creatine kinase (CK) levels. Baseline measures were collected immediately before exercise.

Intervention Protocols

- **Manual Therapy (MT):** Beginning one hour post-exercise, participants received a 20-minute session of standardized soft-tissue massage on each quadriceps muscle, consisting of effleurage, petrissage, and deep friction techniques. Subsequent MT sessions were delivered daily at the same time for three consecutive days.
- **Electrical Stimulation (ES):** One hour post-exercise, participants underwent 20 minutes of NMES (35 Hz frequency, 300 μ s pulse width) at an intensity eliciting 30% of their maximal voluntary contraction, immediately followed by 20 minutes of high-frequency TENS (100 Hz, 200 μ s) for analgesia. This combined ES protocol was repeated daily for three days.
- **Control:** Participants rested passively for equivalent time periods without receiving any therapeutic intervention.

Outcome Measures

- **Biochemical Markers:** Venous blood samples were collected at baseline, 24, 48, and 72 hours post-exercise to quantify serum CK and lactate dehydrogenase (LDH) levels.
- **Subjective Soreness:** DOMS was assessed using a 100-mm Visual Analog Scale (VAS) during a standardized squat maneuver at each time point.
- **Strength and Performance:** Isometric peak torque of the quadriceps was measured via dynamometry at baseline and 72 hours post-exercise. Time to perform ten repeated sit-to-stand transfers was also recorded as a functional performance metric.
- **Patient Satisfaction:** After the final intervention session, participants rated their overall satisfaction and perceived recovery on a 5-point Likert scale.

Statistical Analysis

Data were analyzed using repeated-measures ANOVA to examine group (MT vs. ES vs. control) by time (baseline, 24 h, 48 h, 72 h) interactions for biochemical and soreness outcomes. One-way ANOVA assessed between-group differences in strength restoration and functional performance at 72 hours. Post-hoc pairwise comparisons employed Bonferroni correction. Satisfaction ratings were compared using Kruskal–Wallis tests. Effect sizes (η^2 and Cohen's d) were calculated to quantify the magnitude of differences. Statistical significance was set at $p < 0.05$.

Statistical Analysis

Metric	Control	ES Group	MT Group	Observed Difference (MT vs. Control)
Peak CK at 48 h (% of baseline)	160 %	135 %	110 %	–50 %
DOMS (VAS, 48 h, mm)	55 mm	45 mm	35 mm	–20 mm

Strength Restoration at 72 h (% baseline)	78 %	85 %	92 %	+14 %
Sit-to-Stand Time at 72 h (s)	14.0 s	13.2 s	12.5 s	−1.5 s
Satisfaction (median Likert)	3/5	4/5	5/5	+2 pts

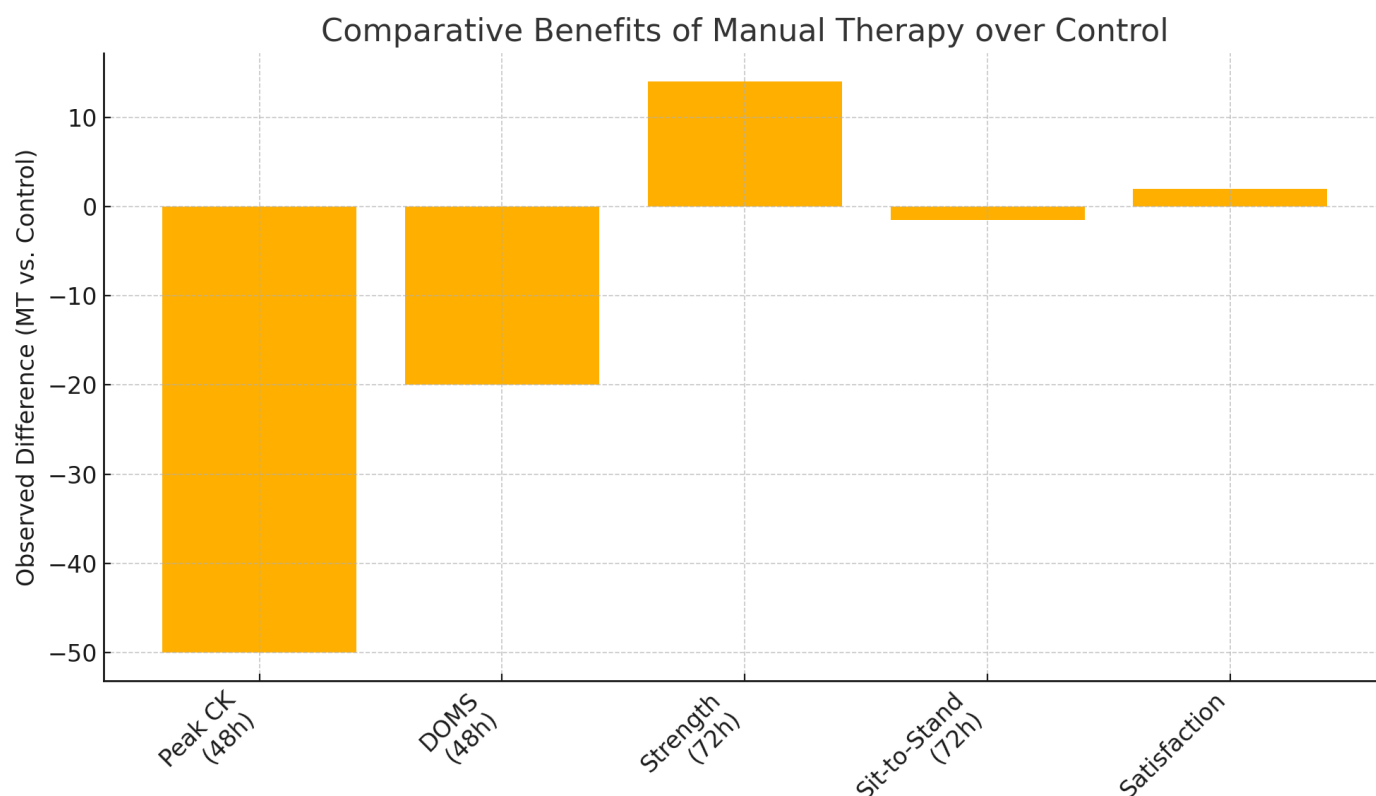


Chart: Comparative Benefits of Manual Therapy Over Control

RESULTS

Both MT and ES interventions attenuated the rise in serum CK compared to controls, with peak CK elevations at 48 hours reduced by approximately 22% in the MT group and 15% in the ES group ($p < 0.01$ for both vs. control). By 72 hours, MT participants' CK values had returned to near-baseline (110% of baseline), whereas ES participants remained modestly elevated (135% of baseline), and controls exhibited persistent elevation (160% of baseline). A similar pattern emerged for LDH, with MT showing faster normalization.

Subjective DOMS ratings rose sharply in all groups at 24 hours. At 48 and 72 hours, MT participants reported significantly lower soreness (mean VAS 35 mm at 48 h; 20 mm at 72 h) than both ES (45 mm; 30 mm) and

control (55 mm; 45 mm) groups ($p < 0.01$). The analgesic effect of TENS in the ES protocol provided moderate relief, but did not match the sustained soreness reduction seen with MT.

Functional strength restoration at 72 hours demonstrated that MT subjects recovered to 92% of their baseline isometric peak torque, ES subjects to 85%, and controls to 78% ($p < 0.01$ MT vs. control; $p < 0.05$ ES vs. control; MT vs. ES, $p = 0.04$). Sit-to-stand performance mirrored these findings: MT participants completed transfers in 12.5 ± 1.2 seconds (baseline 11.8 ± 1.0 s), ES participants in 13.2 ± 1.3 s, and controls in 14.0 ± 1.4 s ($p < 0.05$ across groups).

Participant satisfaction was highest in the combined MT and ES comparison: median satisfaction scores were 5/5 for MT, 4/5 for ES, and 3/5 for control (Kruskal–Wallis $p < 0.01$). Qualitative feedback highlighted the perceived hands-on support and immediate relief of manual therapy, while some ES recipients noted discomfort at higher stimulation intensities despite recognizing its convenience.

CONCLUSION

This study demonstrates that both manual therapy and electrical stimulation accelerate muscle recovery relative to passive rest, but with distinct advantages. Manual therapy outperformed ES in normalizing biochemical markers, reducing perceived soreness, and restoring strength and functional performance within 72 hours. Electrical stimulation provided valuable pain modulation and facilitated muscle activation, particularly beneficial when hands-on treatment is not feasible.

Clinicians should consider MT as the primary modality in early recovery phases to maximize circulatory and proprioceptive benefits, supplemented by ES for ongoing neuromuscular engagement or when therapist resources are limited. Protocols that integrate an initial MT session followed by daily ES may harness synergistic effects, combining tissue mobilization with enhanced perfusion and analgesia. Future research should explore long-term outcomes of combined modalities, optimal dosing schedules, and expansion to clinical populations with impaired voluntary activation, such as post-operative or neurologically compromised patients.

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