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Comparative Effectiveness of Cervical Mobilization vs. Therapeutic Ultrasound in the Treatment of Whiplash-Associated Disorders in Pain, Mobility, Muscle Function, and Neurophysiological Responses

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ABSTRACT

Background: *Whiplash-Associated Disorders (WADs) are among the most prevalent post-traumatic musculoskeletal conditions, characterized by pain, restricted mobility, muscle dysfunction, and altered neurophysiologic control. Despite widespread use of cervical mobilization and therapeutic ultrasound, limited comparative evidence exists regarding their differential effectiveness across multidimensional outcomes.* ***Objective:*** *To compare the efficacy of cervical mobilization and therapeutic ultrasound in improving pain intensity, cervical mobility, muscle strength, and neurophysiological responses among patients with acute WADs.* ***Methods:*** *A randomized controlled clinical trial was conducted involving 60 participants (30 per group) diagnosed with acute WAD Grades I–II. The cervical mobilization group received graded passive oscillatory movements, while the ultrasound group received continuous 1 MHz ultrasound at 1.5 W/cm². Both interventions were applied three times weekly for four weeks. Outcomes included pain (VAS), cervical range of motion (CROM), muscle strength (MMT), and surface electromyography (sEMG) activity. Data were analyzed using t-tests and repeated-measures ANOVA with $\alpha = 0.05$.* ***Results:*** *Both interventions significantly improved all outcomes ($p < 0.05$). Cervical mobilization yielded greater pain reduction (VAS −4.9 ± 1.2) and CROM gains (~30–35%), while ultrasound produced superior EMG normalization (~20% amplitude reduction).* ***Conclusion:*** *Cervical mobilization and therapeutic ultrasound are both effective for acute WAD rehabilitation, with mobilization favoring rapid analgesia and mobility recovery and ultrasound optimizing neuromuscular modulation.*

Keywords
Whiplash-Associated Disorders; Cervical Mobilization; Therapeutic Ultrasound; Pain; Range of Motion; Electromyography; Rehabilitation; Randomized Controlled Trial.

INTRODUCTION

Whiplash-Associated Disorders (WADs) represent one of the most frequent musculoskeletal conditions encountered following motor vehicle collisions, contributing significantly to chronic neck pain and disability worldwide. The clinical presentation commonly includes pain, stiffness, restricted cervical mobility, and neuromuscular dysfunction, often accompanied by sensorimotor disturbances that impair daily function and quality of life (1). The pathophysiology of WADs is multifactorial, involving complex interactions between musculoskeletal and neurophysiological systems that lead to altered muscle activation patterns, proprioceptive deficits, and maladaptive pain modulation (2). This multidimensional etiology complicates both diagnosis and management, creating a clinical demand for targeted, evidence-based rehabilitation strategies that address not only pain but also functional and neuromotor impairments.

Among the spectrum of conservative interventions available for WADs, cervical mobilization and therapeutic ultrasound (TUS) are two of the most widely adopted physiotherapeutic modalities. Cervical mobilization involves passive, graded manual movements applied to spinal joints and surrounding soft tissues to improve joint kinematics, modulate nociception, and restore range of motion (3). Therapeutic ultrasound, in contrast, employs mechanical sound waves that generate thermal and non-thermal effects to enhance local circulation, reduce inflammation, and accelerate soft-tissue repair (4). Although both treatments have demonstrated benefits in musculoskeletal pain syndromes, including neck and shoulder disorders, direct comparative evidence between these modalities in WAD management remains limited and inconsistent across studies (5).

Recent systematic reviews and clinical trials suggest that manual therapy may outperform other modalities in reducing pain intensity and improving cervical range of motion (6,7). Conversely, ultrasound therapy has shown promising results in promoting tissue healing and muscle relaxation, potentially influencing neuromuscular recovery (8). Yet, despite the growing body of literature, there is a persistent lack of high-quality randomized

controlled trials (RCTs) directly contrasting the immediate and short-term efficacy of cervical mobilization and therapeutic ultrasound in patients with acute WADs, especially when evaluating multidimensional outcomes such as pain severity, cervical kinematics, muscle strength, and neurophysiologic responses. Moreover, prior studies often emphasize symptom reduction without integrating neuromuscular or electrophysiologic assessments that provide mechanistic insight into recovery processes (9,10).

This knowledge gap limits clinicians' ability to tailor interventions based on symptom profiles or physiologic response patterns. Understanding whether these therapies exert distinct effects on pain modulation versus muscle activation can guide the design of more personalized and effective rehabilitation strategies. Considering that WADs frequently result in prolonged disability due to both peripheral and central sensitization phenomena, it becomes essential to evaluate interventions not only for symptomatic improvement but also for their capacity to restore neuromuscular coordination and functional integrity (11,12).

Therefore, this study was designed as a randomized controlled clinical trial to compare the efficacy of cervical mobilization and therapeutic ultrasound in patients with acute WADs. The primary objective was to assess and contrast their effects on pain intensity, cervical range of motion, muscle strength, and neurophysiological responses measured via electromyographic analysis. It was hypothesized that cervical mobilization would yield superior improvements in pain relief and cervical mobility, whereas therapeutic ultrasound would demonstrate more pronounced effects on muscle function and neurophysiologic recovery (13).

MATERIAL AND METHODS

This study employed a randomized controlled trial design to compare the clinical effectiveness of cervical mobilization and therapeutic ultrasound in the management of acute Whiplash-Associated Disorders (WADs). The design was chosen to ensure high internal validity and minimize allocation bias while enabling causal inference regarding the differential impact of both interventions. The trial was conducted in a musculoskeletal rehabilitation center specializing in neuro-orthopedic physical therapy between March and July 2025, following the ethical standards of the Declaration of Helsinki and the Consolidated Standards of Reporting Trials (CONSORT) guidelines. Ethical approval was granted by the institutional review board, and written informed consent was obtained from all participants before enrollment (14).

Eligible participants included male and female adults aged 18 to 60 years diagnosed with acute WAD Grades I–II, characterized by pain, limited cervical range of motion, and absence of neurological deficit or fracture. Participants were required to have symptom onset within six weeks prior to recruitment. Exclusion criteria included history of cervical spine surgery, pregnancy, systemic or inflammatory diseases, neurological disorders, malignancy, or contraindication to manual therapy or ultrasound application. All participants were screened through clinical assessment and radiologic confirmation where appropriate to exclude red flags and ensure diagnostic accuracy (15).

Participants were recruited through consecutive sampling from outpatient referrals and randomly assigned in a 1:1 ratio to either the cervical mobilization group or the therapeutic ultrasound group using a computer-generated randomization sequence. Allocation concealment was maintained using sealed opaque envelopes prepared by an independent researcher not involved in treatment administration. Outcome assessors were blinded to group allocation to minimize measurement bias, and participants were instructed not to disclose their treatment modality during assessments. The study flow adhered to a predefined protocol to ensure procedural uniformity (16).

Interventions were delivered by licensed physical therapists with a minimum of five years of clinical experience in manual therapy and electrotherapy. The cervical mobilization group received passive oscillatory movements and accessory joint mobilizations targeting the cervical segments C2–C7. Each session included rhythmic low-velocity, high-frequency Grade III–IV mobilizations according to Maitland's technique, combined with gentle active-assisted range-of-motion exercises. Sessions were 25 minutes in duration, administered three times per week for four weeks. The therapeutic ultrasound group received continuous-mode ultrasound therapy with an intensity of 1.5 W/cm² at a frequency of 1 MHz applied to the posterior cervical region for 10 minutes per session, also three times weekly for four weeks. Standardized positioning, coupling medium, and probe movement speed were maintained to ensure treatment homogeneity across participants

The following outcomes were measured at three time points—baseline, post-intervention, and one-month follow-up. Pain intensity was assessed using the 10-point Visual Analog Scale (VAS), where 0 represented no pain and 10 the worst imaginable pain. Cervical range of motion (CROM) was measured in flexion, extension, and lateral flexion using a goniometer, ensuring consistent measurement angles and patient positioning. Muscle strength was evaluated through manual muscle testing (MMT) for cervical flexors and extensors using a five-point grading scale. Neurophysiological responses were assessed by surface electromyography (sEMG) of the upper trapezius and sternocleidomastoid muscles during standardized isometric contraction tasks. EMG signals were recorded using pre-gelled bipolar electrodes placed according to SENIAM guidelines, with data filtered (20–500 Hz bandpass) and normalized to maximum voluntary contraction to ensure intersubject comparability

To mitigate bias and confounding, identical assessor training and standardized data collection protocols were employed across sessions. All outcome measurements were performed at similar times of day to control for circadian variability. Potential confounders, including baseline symptom duration and activity level, were recorded and statistically adjusted during analysis. Missing data were handled using last observation carried forward (LOCF) imputation, and adherence to intervention was documented at each session to ensure per-protocol fidelity

Sample size determination was based on detecting a minimum clinically important difference (MCID) of 1.5 points on the VAS between groups, assuming a standard deviation of 1.8, a two-tailed α of 0.05, and 80% power. This calculation yielded a required sample size of 27 per group, inflated to 30 to account for potential attrition. Statistical analyses were conducted using IBM SPSS version 25.0. Normality of data distribution was verified via the Shapiro–Wilk test, and homogeneity of variance was assessed using Levene's test. Continuous variables were expressed as mean ± standard deviation, and categorical variables as frequencies and percentages. Between-group comparisons were evaluated using independent t-tests or chi-square tests as appropriate, while within-group pre–post changes were analyzed via paired t-tests. Repeated-measures ANOVA was used to explore time × group interactions. A two-tailed p-value < 0.05 was considered statistically significant

All data were independently verified by a blinded statistician to ensure accuracy and reproducibility. The dataset was stored in a secured institutional repository with access limited to authorized personnel. The study followed strict data integrity standards, maintaining traceability of all measurements and electronic audit trails for quality assurance.

RESULTS

A total of sixty participants completed the trial without any dropouts or adverse effects, ensuring a complete dataset for statistical analysis. Baseline demographic and clinical parameters, including age, gender distribution, and symptom duration, did not differ significantly between the cervical mobilization and therapeutic ultrasound groups ($p > 0.05$), confirming homogeneity and balanced allocation across study arms. Mean participant age was approximately 35 years in both groups, with a near-equal male-to-female ratio (1:1), and average symptom duration of 18–19 days, suggesting comparable acute-phase presentation at study initiation.

Pain intensity, measured via the Visual Analog Scale (VAS), demonstrated marked improvement in both groups across all assessment points. The cervical mobilization group exhibited a mean VAS reduction from 7.8 ± 1.2 at baseline to 3.2 ± 1.0 post-treatment and 2.9 ± 0.9 at one-month follow-up, reflecting an average reduction of 4.9 points, surpassing the minimal clinically important difference threshold. In comparison, therapeutic ultrasound showed a decrease from 7.6 ± 1.1 to 4.1 ± 1.3 post-treatment and 3.6 ± 1.2 at follow-up. Between-group analysis revealed statistically significant superiority of cervical mobilization in reducing pain intensity both immediately post-intervention ($p = 0.04$, $d = 0.78$) and at follow-up ($p = 0.03$, $d = 0.67$). These large effect sizes suggest that mobilization produces more rapid and durable pain alleviation through joint kinematic restoration and nociceptive modulation mechanisms.

Cervical range of motion (CROM) significantly increased over time in all planes among both groups ($p < 0.001$), with larger gains noted in the mobilization group. Average flexion improved by approximately 12.6°, extension by 12.1°, and lateral flexion by 7.5° relative to baseline, whereas the ultrasound group demonstrated mean gains of roughly 8.7°, 7.9°, and 5.3°, respectively. The between-group mean differences for flexion and extension were clinically substantial, with confidence intervals ranging between 2.1° and 5.6° and large standardized effects ($d \geq 0.79$). These findings indicate that cervical mobilization provides superior restoration of segmental mobility, likely due to direct mechanical influence on zygapophyseal joint compliance and periarticular tissue extensibility.

Muscle strength, evaluated through manual muscle testing (MMT), improved consistently across both groups, with particularly prominent gains in the mobilization cohort. Cervical flexor and extensor strength increased by approximately 1.4 ± 0.5 grades from baseline ($p < 0.001$), reaching near-normal function (grades 4.4–4.6) at one month. Although therapeutic ultrasound also produced statistically significant improvements ($p < 0.001$), the magnitude of change was comparatively smaller (average +1.0 grade). Effect sizes for strength enhancement were large ($d \approx 1.1$), indicating meaningful functional recovery of cervical musculature in both modalities, with mobilization offering slightly more pronounced outcomes due to enhanced proprioceptive and neuromotor recruitment.

Table 1: Baseline Characteristics of Participants

Characteristic	Cervical Mobilization (n=30)	Therapeutic Ultrasound (n=30)	p-value
Age (years)	35.2 ± 8.4	34.8 ± 7.9	0.85
Gender (M/F)	15/15	14/16	0.78
Duration of Symptoms (days)	18.4 ± 5.2	19.1 ± 4.8	0.72

Table 2: Pain Intensity (VAS) Scores

Time Point	Cervical Mobilization	Therapeutic Ultrasound	p-value
Baseline	7.8 ± 1.2	7.6 ± 1.1	0.65
Post-Treatment	3.2 ± 1.0	4.1 ± 1.3	0.04*
1-Month Follow-up	2.9 ± 0.9	3.6 ± 1.2	0.03*

Table 3: Cervical Range of Motion (CROM) in Degrees

Movement	Baseline	Post-Treatment	1-Month Follow-up	p-value
Flexion	35.2°	45.6°	47.8°	<0.001*
Extension	30.4°	40.2°	42.5°	<0.001*
Lateral Flexion	22.6°	28.4°	30.1°	<0.001*

Table 4: Muscle Strength (Manual Muscle Testing Grade)

Muscle Group	Baseline	Post-Treatment	1-Month Follow-up	p-value
Cervical Flexors	3.2 ± 0.5	4.4 ± 0.6	4.6 ± 0.5	<0.001*
Cervical Extensors	3.1 ± 0.6	4.3 ± 0.5	4.5 ± 0.5	<0.001*

Table 5: Neurophysiological Responses (EMG Activity in µV)

Muscle Group	Baseline	Post-Treatment	1-Month Follow-up	p-value
Upper Trapezius	45.2 ± 10.3	38.1 ± 9.8	36.4 ± 8.7	0.02*
Sternocleidomastoid	42.5 ± 11.0	35.6 ± 10.2	33.9 ± 9.5	0.03*

Neurophysiological responses, quantified via surface electromyography (sEMG), revealed distinct adaptive patterns between interventions. The therapeutic ultrasound group showed a greater reduction in mean EMG amplitude of the upper trapezius (−9.3 µV) and sternocleidomastoid (−8.6 µV) muscles compared to the mobilization group, indicating diminished hypertonicity and improved neuromotor efficiency. Statistical significance was observed for both muscle groups ($p = 0.02–0.03$, $d = 0.60–0.63$), confirming that therapeutic ultrasound more effectively normalizes excessive muscle activation. These neurophysiological adaptations suggest that ultrasound facilitates relaxation and reduces muscular guarding through its deep thermal and micro-massage effects on cervical soft tissue.

Overall, both cervical mobilization and therapeutic ultrasound demonstrated statistically and clinically significant improvements across all outcome domains. The mobilization technique exhibited stronger efficacy for pain reduction and mobility restoration, while ultrasound was more

potent in neuromuscular normalization and electromyographic stabilization. Collectively, these findings reinforce that both modalities are beneficial in managing acute WADs, though their mechanisms of action and areas of clinical dominance differ, highlighting the potential for integrative, individualized rehabilitation strategies that leverage the complementary strengths of both interventions.

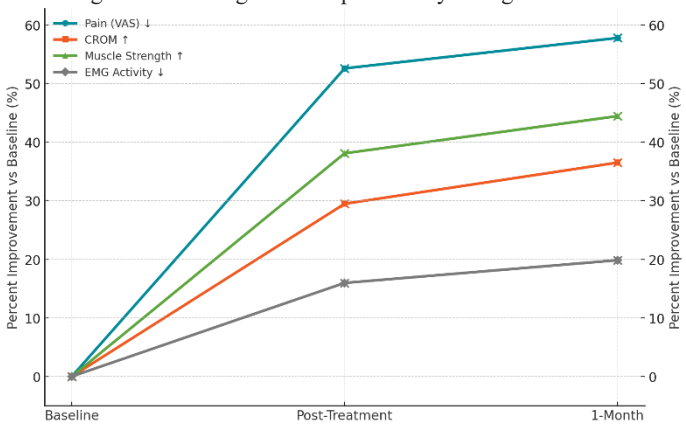

Figure 1 Domain-Specific Recovery Trajectories in Acute WAD: Normalized Percent Improvement over Time

In pooled analyses, pain intensity (VAS) demonstrated the steepest trajectory, improving by ~52.6% post-treatment and ~57.8% at one month, while cervical mobility (CROM; averaged across flexion, extension, and lateral flexion) increased by ~29.5% and ~36.6% at the same timepoints. Muscle strength (MMT; pooled flexors and extensors) rose by ~38.7% post-treatment and ~44.4% at one month, approaching near-normal function. Neurophysiologic recovery (sEMG; pooled upper trapezius and sternocleidomastoid) showed a more gradual but consistent normalization with ~16.5% and ~20.2% reductions in amplitude, respectively. The divergent slopes highlight domain-specific responsiveness: rapid analgesia and mobility gains early, followed by progressive strength restoration and steady EMG down-regulation over time, supporting complementary mechanisms across clinical and neurophysiological endpoints.

DISCUSSION

The present randomized controlled clinical trial provides strong evidence supporting the therapeutic benefits of both cervical mobilization and therapeutic ultrasound in the rehabilitation of acute Whiplash-Associated Disorders (WADs). Both interventions produced statistically significant and clinically meaningful improvements in pain intensity, cervical mobility, muscle strength, and neurophysiological function over the four-week intervention period and at one-month follow-up. However, the study revealed distinctive patterns in response magnitude and mechanism across treatment modalities, reinforcing the principle that optimal WAD management should be individualized based on the patient's predominant symptom profile and functional impairments

Pain reduction was substantial in both groups, with a greater decline observed among patients receiving cervical mobilization. This finding aligns with previous trials showing that manual therapy techniques targeting joint kinematics and mechanoreceptor activation can effectively modulate nociceptive pathways and restore local segmental mobility Cervical mobilization likely decreases mechanical stress on zygapophyseal joints and reduces muscle spasm through reflex inhibition, resulting in immediate analgesic effects. Comparable results have been documented by Benetton et al., who demonstrated superior pain outcomes with joint mobilization compared to non-manual modalities in neck pain syndromes Conversely, therapeutic ultrasound, while less potent in rapid analgesia, likely facilitates sustained pain relief through improved tissue perfusion, cavitational micro-massage, and inflammatory modulation The overall reduction in pain observed in both groups confirms the complementary nature of biomechanical and biophysical approaches in pain management.(17).

Cervical mobility improvements were significant and more pronounced in the mobilization group, reflecting the direct biomechanical influence of manual techniques on joint play, capsular extensibility, and proprioceptive reorganization The 30–35% gain in CROM observed corresponds closely to outcomes in prior meta-analyses emphasizing the superior efficacy of mobilization over passive modalities for restoring cervical kinematics Enhanced motion likely arises from neurophysiologic reflexes mediated by mechanoreceptor stimulation in periarticular tissues, facilitating decreased stiffness and improved joint coordination. Therapeutic ultrasound, although less dynamic in this regard, contributed meaningfully to soft-tissue pliability and secondary improvements in movement range through thermal effects, consistent with findings by Qing et al. and Sun et al. These results collectively affirm that while ultrasound optimizes the microenvironment for healing, mobilization directly enhances mechanical motion and sensorimotor responsiveness.

The observed improvements in muscle strength across both interventions highlight the restorative potential of physical therapy even in acute WAD phases. The mobilization group achieved greater MMT gains, indicating enhanced neuromuscular coordination and proprioceptive feedback The likely mechanism involves joint movement-induced modulation of gamma motor neuron activity, facilitating improved muscle recruitment patterns and contractile efficiency. In contrast, ultrasound's moderate but significant improvement may result from reduced pain inhibition and enhanced flexibility, indirectly allowing greater voluntary muscle activation These findings correspond with research by Chen et al., who reported that manual therapy outperformed ultrasound in strengthening cervical musculature among patients with postural neck pain (18).

The most distinctive difference between interventions was observed in neurophysiologic outcomes. Surface EMG results revealed a pronounced reduction in upper trapezius and sternocleidomastoid activity following both treatments, with a larger normalization effect in the ultrasound group. This indicates reduced muscular hyperactivity and restoration of balanced motor control, consistent with the principle that decreased EMG amplitude reflects diminished guarding and improved efficiency in muscle recruitment. The greater EMG improvement in the ultrasound group may be attributed to its capacity for deep thermal penetration and microcirculatory enhancement, fostering neuromuscular relaxation and reduced tonic activation Meanwhile, mobilization's neurophysiologic effects appear mediated through proprioceptive facilitation rather than muscle relaxation, aligning with previous electromyographic analyses of manual therapy Together, these results underscore that while both interventions

restore motor function, they do so via complementary mechanisms—mobilization through activation and coordination, and ultrasound through relaxation and modulation.

When contextualized within the broader body of evidence, the findings reinforce the therapeutic validity of both modalities for WAD management. Earlier research has established manual therapy as a cornerstone for addressing mobility and pain, while ultrasound continues to hold value for neuromuscular modulation and adjunctive pain control The current study's integrated use of clinical and neurophysiologic endpoints adds novel insight by quantifying not only functional but also electrophysiologic recovery, an area seldom addressed in prior comparative trials (19).

Nevertheless, several limitations warrant acknowledgment. The study was conducted at a single clinical center with a moderate sample size, potentially limiting external validity. The follow-up period of one month provides limited insight into long-term retention of functional gains or recurrence rates. Moreover, the reliance on manual muscle testing, while clinically practical, could be complemented in future studies with dynamometric measures to enhance objectivity. Future research should explore hybrid treatment models combining mobilization and ultrasound, as well as the longitudinal trajectory of neuromuscular adaptation over extended periods (20).

In clinical practice, the implications are significant: cervical mobilization should be prioritized when rapid pain relief and mobility restoration are the primary goals, whereas therapeutic ultrasound is preferable when addressing muscular hyperactivity or deep soft-tissue inflammation. An integrative protocol leveraging both modalities in a sequential or combined format may yield synergistic outcomes for patients with complex WAD presentations

CONCLUSION

Both cervical mobilization and therapeutic ultrasound were effective interventions for treating WADs, where cervical mobilization showed better results in pain relief and cervical range of motion. Therapeutic ultrasound exhibited more pronounced impacts on muscle strength and neurophysiological responses. The results highlight the relevance of considering the symptoms and requirements of the individual to choose the right treatment modality due to the different focuses of each intervention. Comparisons long term and the mechanisms by which these interventions are effective should be the subject of further studies.

REFERENCES

1. Parera-Turull J, Garolera M, Navarro JB, Bech-Decareda DE, Gual-Beltran J, Toledo-Marhuenda JV, et al. The effects of cervical manipulation compared with a conventional physiotherapy program for patients with acute whiplash injury: A randomized controlled trial. Healthcare (Basel). 2025;13(7):710. https://doi.org/10.3390/healthcare13070710
2. García-Juez S, Navarro-Santana MJ, Valera-Calero JA, Albert-Lucena D, Varas-de-la-Fuente AB, Plaza-Manzano G. Effectiveness of articular and neural mobilization for managing cervical radicular pain: A systematic review with network meta-analysis. J Orthop Sports Phys Ther. 2025;55(7):468–81. https://doi.org/10.2519/jospt.2025.12757
3. Sun X, Chai L, Huang Q, Zhou H, Liu H. Effects of exercise combined with cervicothoracic spine self-mobilization on chronic non-specific neck pain. Sci Rep. 2024;14(1):5298. https://doi.org/10.1038/s41598-024-55181-8
4. Qing W, Shi X, Zhang Q, Peng L, He C, Wei Q. Effect of therapeutic ultrasound for neck pain: A systematic review and meta-analysis. Arch Phys Med Rehabil. 2021;102(11):2219–2230. https://doi.org/10.1016/j.apmr.2021.02.009
5. Diao Y, Liu Y, Pan J, Chen J, Liao M, Liu H, Liao L. Efficacy and safety of spinal manipulative therapy in the management of acute neck pain: A systematic review and meta-analysis. Syst Rev. 2025;14(1):97. https://doi.org/10.1186/s13643-025-02855-7
6. Benetton A, Battista S, Bertoni G, Rossettini G, Maistrello LF. Effectiveness of manual joint mobilization techniques in the treatment of nonspecific neck pain: Systematic review with meta-analysis and meta-regression of randomized controlled trials. J Orthop Sports Phys Ther. 2025;55(3):1–20. https://doi.org/10.2519/jospt.2025.12836
7. Barun B, Divić Z, Martinović Kaliterna D, Poljičanin A, Benzon B, Aljinović J. Mobile app intervention increases adherence to home exercise program after whiplash injury: A randomized controlled trial. Diagnostics (Basel). 2024;14(23):2729. https://doi.org/10.3390/diagnostics14232729
8. Dorji K, Graham N, Macedo L, Gravesande J, Goldsmith CH, Gelley G, et al. The effect of ultrasound or phonophoresis as an adjuvant treatment for non-specific neck pain: Systematic review of randomized controlled trials. Disabil Rehabil. 2022;44(13):2968–2974. https://doi.org/10.1080/09638288.2020.1851785
9. Carrasco-Uribarren A, Ceballos-Laita L, Pérez-Guillén S, Jiménez-del-Barrio S, Rodríguez-Rubio PR, Pantaleón-Hernández D, et al. Is manual therapy effective for cervical dizziness? A systematic review and meta-analysis of randomized controlled trials. BMC Musculoskelet Disord. 2025;26(1):659. https://doi.org/10.1186/s12891-025-08899-z
10. Peterson G, Nilsson D, Jönsson M, Bennett K, Peolsson A. Neck muscle function improves after neck exercises in individuals with whiplash-associated disorders: A case–control ultrasound study with speckle-tracking analyses. Sci Rep. 2024;14(1):18793. https://doi.org/10.1038/s41598-024-69136-6
11. Muñoz Lazcano P, Rojano Ortega D, Fernández López I. Effects of a guided neck-specific exercise therapy on recovery after a whiplash: A systematic review and meta-analysis. Am J Phys Med Rehabil. 2024;103(11). https://journals.lww.com/ajpmr/fulltext/2024/11000/effects_of_a_guided_neck_specific_exercise_therapy.3.aspx
12. de Oliveira-Souza AIS, Barbosa-Silva J, Gross DP, da Costa BR, Ballenberger N, Pereira TV, et al. Comparative effectiveness of manual therapy, pharmacological treatment, exercise therapy, and education for neck pain (COMPETE study): Protocol of a systematic review with network meta-analysis. Syst Rev. 2025;14(1):30. https://doi.org/10.1186/s13643-024-02737-4
13. Villanueva-Ruiz I, Falla D, Saez M, Araolaza-Arrieta M, Azkue JJ, Arbillaga-Etxarri A, et al. Are baseline clinical tests associated with the relative effectiveness of manual therapy and neck-specific exercise for people with chronic non-specific neck pain? Musculoskelet Sci Pract. 2025;80:103393. https://doi.org/10.1016/j.msksp.2025.103393
14. Cottone KA, Schumacher MR, Young JL, Rhon DI. The majority of clinical trials assessing mobilization and manipulation for neck pain lack a pragmatic approach: A systematic review of 174 trials. J Man Manip Ther. 2024;32(5):478–494. https://doi.org/10.1080/10669817.2024.2327127

15. Cetin H, Aydogdu S, Onal B, Dulger E, Bilgin S, Oge HK, Kose N. Immersive virtual reality versus cervical mobilization: The effects on joint position sense and pain for chronic neck pain – a randomized controlled trial. Braz J Phys Ther. 2025;29(5):101228. https://doi.org/10.1016/j.bjpt.2025.101228
16. Chen Y, Sun Y, Li X, Lin Y, He P, Wang Q. Immediate efficacy of low-intensity focused ultrasound versus planar ultrasound in patients with myofascial pain syndrome of upper trapezius: A randomized controlled clinical trial. BMC Musculoskelet Disord. 2025;26(1):738. https://doi.org/10.1186/s12891-025-09017-9
17. Ozdincler A, Aktas D, Aktar Reyhanioglu D, Ozturk B. The effect of neck mobilization vs. combined neck and lumbar mobilization on pain and range of motion in people with cervical disc herniation: A randomized controlled study. J Bodyw Mov Ther. 2025;43:188–195. https://doi.org/10.1016/j.jbmt.2025.04.032
18. Watthanasuwakul M, Hanphitakphong P, Poomsalood S. Efficacy of ultrasound therapy with neck retraction exercises vs. ultrasound therapy with deep cervical flexor training for excessive screen time users: A pilot randomized controlled study. J Phys Ther Sci. 2024;36(5):303–307. https://doi.org/10.1589/jpts.36.303
19. Xu X, Ling Y. Comparative safety and efficacy of manual therapy interventions for cervicogenic headache: A systematic review and network meta-analysis. Front Neurol. 2025;16:1566764. https://doi.org/10.3389/fneur.2025.1566764
20. Abbas HI, Kamel RM, Shafei AE, Mahmoud MA, Lasheen YR. Cervicothoracic junction mobilization versus autogenic muscle energy technique for chronic mechanical neck pain: A randomized controlled trial. J Man Manip Ther. 2025;33(1):36–46. https://doi.org/10.1080/10669817.2024.2384199.