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Comparative Effectiveness of Cervical Spine Mobilization vs. Neuromuscular Re-Education for Cervicogenic Dizziness on Pain, Balance, Function, and Cervical Mobility

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ABSTRACT

Background: Cervicogenic dizziness is characterized by dizziness and postural instability associated with cervical spine dysfunction and is often accompanied by neck pain and restricted cervical motion, yet comparative evidence for manual versus active sensorimotor rehabilitation remains limited. Objective: To compare the effectiveness of cervical spine mobilization versus neuromuscular re-education on pain, balance, dizziness-related disability, and cervical mobility in adults with cervicogenic dizziness. Methods: A prospective, single-blind randomized controlled trial enrolled 70 participants clinically diagnosed with cervicogenic dizziness and allocated them to cervical spine mobilization (n=35) or neuromuscular re-education (n=35). Interventions were delivered three times weekly for eight weeks. Outcomes included Visual Analogue Scale (VAS), Balance Error Scoring System (BESS), Dizziness Handicap Inventory (DHI), and active cervical range of motion (rotation and flexion), assessed at baseline, Week 4, and Week 8. Between-group mean differences, 95% confidence intervals, and Cohen's d were reported. Results: Both groups improved significantly over time. At Week 8, cervical spine mobilization produced greater pain reduction (mean difference −1.20; 95% CI −1.63 to −0.77; p=0.001; d=−1.30) and greater improvements in rotation (12.0°; 95% CI 7.5–16.5; p=0.002; d=1.26) and flexion (8.0°; 95% CI 4.0–12.0; p=0.01; d=0.94). Neuromuscular re-education yielded superior balance improvement (BESS mean difference 3.40; 95% CI 2.27–4.53; p=0.01; d=1.44). DHI improvements were comparable (p=0.36). Conclusion: Both interventions are effective; mobilization favors pain and mobility, whereas neuromuscular re-education favors balance, supporting deficit-guided treatment selection.

Keywords

cervicogenic dizziness; cervical spine mobilization; neuromuscular re-education; balance; neck pain; cervical mobility.

INTRODUCTION

Cervicogenic dizziness (CGD) is a clinically challenging disorder characterized by sensations of disequilibrium and postural unsteadiness that are temporally associated with neck movement or sustained cervical postures and often coexist with neck pain and restricted cervical mobility. The syndrome is increasingly recognized in individuals with chronic cervical dysfunction, where altered afferent input from cervical joints and deep neck musculature is proposed to distort sensorimotor integration and compromise postural control. This disruption can lead to functional limitations and increased fall risk, particularly in adults with persistent symptoms and movement-related exacerbation. Although the exact pathophysiological mechanisms remain multifactorial, impaired proprioceptive acuity and neuromuscular inefficiency are consistently implicated, supporting the use of conservative rehabilitative interventions targeting both pain and cervical sensorimotor control (1).

Current non-pharmacological management strategies for CGD typically emphasize manual therapy and therapeutic exercise approaches that aim to restore cervical joint mechanics, reduce pain-related disability, and improve postural stability. Mobilization-based interventions are widely used because graded oscillatory glides and traction are believed to reduce pain, improve segmental movement, and normalize mechanoreceptor-driven afferent input, which may indirectly enhance postural orientation and motor control. Comparable therapeutic logic underlies structured exercise-based rehabilitation in cervical disorders, where improvements in neuromuscular efficiency and postural control have been reported following targeted interventions, particularly when movement training and proprioceptive elements are included (1). Similarly, aerobic and stabilization-oriented programs are known to enhance physical performance and reduce fall risk in chronic musculoskeletal populations, reinforcing the relevance of balance-oriented rehabilitation strategies in dizziness-related syndromes where instability is a key clinical feature (2).

Neuromuscular re-education (NMR) represents an active rehabilitation approach emphasizing proprioceptive retraining, coordinated cervical movement, balance training, and stabilization drills designed to improve sensorimotor integration and postural control. Evidence from broader cervical and spine rehabilitation literature supports the concept that neuromuscular control training can improve movement quality, functional performance, and disability outcomes in chronic neuromusculoskeletal conditions, suggesting potential utility in CGD where altered motor control is central to the symptom mechanism (3). Additionally, vestibular-oriented physiotherapy regimens have demonstrated meaningful improvements

in static and dynamic balance among individuals with degenerative cervical conditions, further supporting the hypothesis that active sensorimotor training may provide specific benefit for balance deficits in cervical-associated dizziness presentations (4). In contrast, manual therapy and mobilization techniques have been primarily emphasized for symptom modulation and restoration of mobility, particularly where pain and motion restriction are dominant, and clinical rehabilitation frameworks continue to identify mobilization as a foundational component of cervical dysfunction management (6,7).

Despite clinical use of both approaches, direct comparative evidence between cervical spine mobilization (CSM) and NMR within a randomized controlled framework remains limited, leaving uncertainty regarding which intervention offers superior benefit across key CGD-related outcomes. In particular, it is unclear whether mobilization provides greater improvement in pain and mobility outcomes than active neuromuscular training, and conversely whether NMR provides superior balance restoration compared with mobilization-based care. This knowledge gap is clinically relevant because CGD is multidimensional and requires targeted prioritization of interventions depending on whether the dominant impairment is pain, instability, disability, or restricted motion. Therefore, the objective of this randomized controlled trial was to compare the effectiveness of cervical spine mobilization versus neuromuscular re-education on pain intensity, balance performance, functional disability, and cervical spine mobility in adults with cervicogenic dizziness over an eight-week intervention period. The a priori hypothesis was that cervical spine mobilization would yield greater improvements in pain and cervical range of motion, whereas neuromuscular re-education would yield greater improvements in balance performance (1–7).

MATERIALS AND METHODS

This prospective, single-blind randomized controlled trial was conducted at outpatient physical therapy clinics between January and October 2025 and enrolled adults aged 30–65 years with a clinical diagnosis of cervicogenic dizziness. Participants were eligible if they reported dizziness provoked by neck movement or sustained cervical postures for at least three months, had concurrent neck pain of at least 4/10 on a 10-point Visual Analogue Scale, demonstrated restricted cervical range of motion on clinical assessment, and exhibited clinical findings consistent with cervical dysfunction associated with dizziness. Individuals were excluded if they had a history of vestibular pathology, neurological disease, recent cervical spine surgery, inflammatory joint disease, or any contraindication to manual therapy or therapeutic exercise. All eligible participants provided written informed consent prior to enrollment.

Participants were randomly allocated in a 1:1 ratio into two intervention groups using a computerized randomization sequence. The trial was single-blinded such that outcome assessments were performed by an assessor blinded to group allocation, while participants and treating therapists were not blinded due to the nature of the interventions. Both groups received standardized education regarding posture, ergonomic modification, and adherence to prescribed home activity recommendations. Interventions were delivered three times weekly for eight weeks.

The cervical spine mobilization group received a standardized manual therapy protocol consisting of Grade III–IV rotational and lateral glides applied to clinically identified hypomobile cervical segments, combined with sustained cervical traction. Each treatment session lasted approximately 20 minutes and was performed by a trained physiotherapist. The neuromuscular re-education group received an active rehabilitation protocol including cervical proprioceptive retraining, dynamic balance drills, cervical stabilization exercises, and eye–head coordination tasks designed to improve postural control and coordinated cervical movement. Each session lasted approximately 25 minutes and was delivered at the same frequency and duration as the mobilization group. Home exercise adherence was reinforced at each visit as part of standard trial management.

Outcome assessments were performed at baseline (Week 0), mid-treatment (Week 4), and post-treatment (Week 8). Pain intensity was measured using the Visual Analogue Scale (VAS, 0–10). Balance performance was evaluated using the Balance Error Scoring System (BESS), with higher values reflecting poorer balance due to increased errors. Functional disability associated with dizziness was measured using the Dizziness Handicap Inventory (DHI; 0–100), where higher scores indicate greater disability. Active cervical range of motion (ACROM) was assessed for flexion and rotation using standardized goniometric procedures. Statistical analyses were performed using repeated measures analysis to evaluate within-group changes over time and between-group comparisons at each time point. Independent group comparisons were conducted using two-tailed tests with statistical significance set at $p < 0.05$. Between-group mean differences were reported with 95% confidence intervals, and standardized effect sizes were calculated using Cohen's d for the difference between groups at each time point.

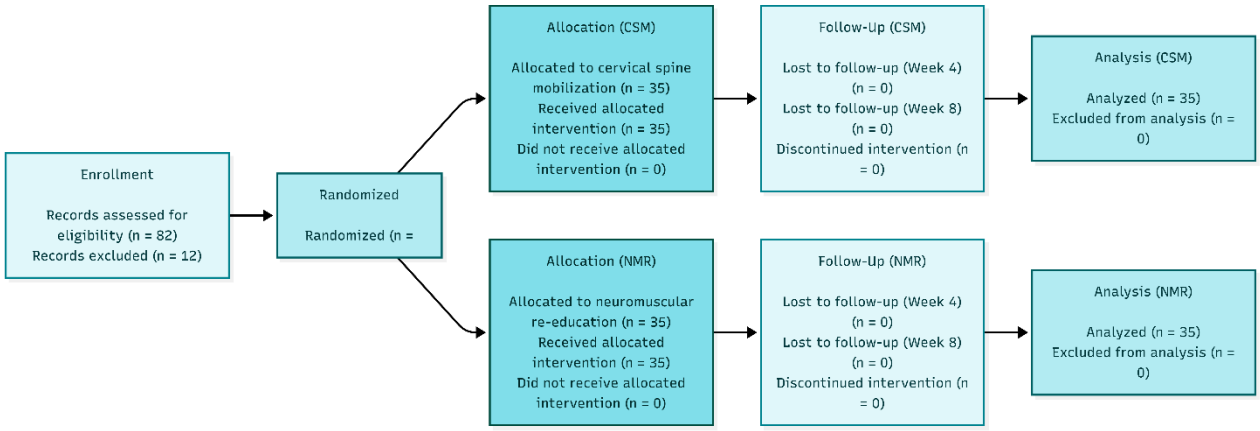

Figure 1 CONSORT Flowchart, Seventy participants with cervicogenic dizziness were randomized equally to cervical spine mobilization (n = 35) or neuromuscular re-education (n = 35). All participants received the allocated intervention, completed follow-up assessments, and were included in the final analysis.

RESULTS

Both groups were comparable at baseline with no statistically significant differences in demographic or clinical variables. Mean age was 46.7 ± 8.4 years in the CSM group and 45.9 ± 7.9 years in the NMR group (p = 0.74). Symptom duration was similar (7.4 ± 2.3 vs 7.6 ± 2.5 months; p = 0.81). Baseline severity of pain (VAS: 6.7 ± 1.2 vs 6.5 ± 1.1; p = 0.58), balance impairment (BESS: 18.1 ± 3.6 vs 17.8 ± 4.0; p = 0.79), and functional disability (DHI: 54.7 ± 10.2 vs 53.9 ± 9.8; p = 0.83) were equivalent between groups, supporting successful randomization and baseline comparability.

Table 1. Baseline Characteristics of Participants

Variable	Group CSM (n=35) Mean ± SD / n	Group NMR (n=35) Mean ± SD / n	p-value
Age (years)	46.7 ± 8.4	45.9 ± 7.9	0.74
Gender (M/F)	16/19	18/17	0.62
Duration of symptoms (months)	7.4 ± 2.3	7.6 ± 2.5	0.81
Baseline VAS (0–10)	6.7 ± 1.2	6.5 ± 1.1	0.58
Baseline BESS (errors)	18.1 ± 3.6	17.8 ± 4.0	0.79
Baseline DHI (0–100)	54.7 ± 10.2	53.9 ± 9.8	0.83

Table 2. Primary Outcomes Over Time (Pain, Balance, Disability)

Outcome	Time	CSM (n=35)	NMR (n=35)	Mean Diff (CSM−NMR)	95% CI	p-value	Cohen's d
		Mean ± SD					
VAS Pain (0–10)	Baseline	6.7 ± 1.2	6.5 ± 1.1	0.20	−0.34 to 0.74	0.58	0.17
	Week 4	4.3 ± 0.9	4.6 ± 1.0	−0.30	−0.75 to 0.15	0.30	−0.32
	Week 8	2.6 ± 0.7	3.8 ± 1.1	−1.20	−1.63 to −0.77	0.001	−1.30
BESS (errors)	Baseline	18.1 ± 3.6	17.8 ± 4.0	0.30	−1.48 to 2.08	0.79	0.08
	Week 4	14.5 ± 3.0	13.2 ± 2.8	1.30	−0.06 to 2.66	0.12	0.45
	Week 8	11.8 ± 2.6	8.4 ± 2.1	3.40	2.27 to 4.53	0.01	1.44
DHI (0–100)	Baseline	54.7 ± 10.2	53.9 ± 9.8	0.80	−3.90 to 5.50	0.83	0.08
	Week 4	40.8 ± 8.5	38.6 ± 7.9	2.20	−1.64 to 6.04	0.45	0.27
	Week 8	28.9 ± 6.2	26.7 ± 5.8	2.20	−0.64 to 5.04	0.36	0.37

Both interventions produced substantial improvement across pain, balance, and disability over the eight-week treatment period. Pain intensity decreased from 6.7 ± 1.2 to 2.6 ± 0.7 in the CSM group and from 6.5 ± 1.1 to 3.8 ± 1.1 in the NMR group. At Week 8, the between-group difference favored CSM with a mean difference of −1.20 points (95% CI: −1.63 to −0.77; p = 0.001) and a large standardized effect size (d = −1.30), indicating clinically meaningful superiority of mobilization for pain reduction. Balance improved in both groups; however, NMR demonstrated superior performance by Week 8 with lower BESS errors (8.4 ± 2.1) compared with CSM (11.8 ± 2.6), yielding a between-group mean difference of 3.40 errors (95% CI: 2.27 to 4.53; p = 0.01) and a large effect size (d = 1.44), supporting a strong advantage of neuromuscular re-education for balance recovery. Functional disability measured by DHI improved substantially in both groups from approximately 54 points to below 30 points by Week 8; however, the between-group difference remained statistically non-significant (mean difference: 2.20; 95% CI: −0.64 to 5.04; p = 0.36), indicating comparable functional disability improvement for both interventions at study completion.

Table 3. Cervical Mobility Outcomes (Rotation and Flexion)

Outcome	Time	CSM Mean ± SD	NMR Mean ± SD	Mean Diff (CSM−NMR)	95% CI	p-value	Cohen's d
Cervical Rotation (°)	Baseline	58 ± 9	60 ± 8	−2.0	−6.0 to 2.0	0.39	−0.23
	Week 8	82 ± 10	70 ± 9	12.0	7.5 to 16.5	0.002	1.26
Cervical Flexion (°)	Baseline	46 ± 7	47 ± 8	−1.0	−4.5 to 2.5	0.65	−0.13
	Week 8	68 ± 9	60 ± 8	8.0	4.0 to 12.0	0.01	0.94

Cervical mobility improved in both groups, with significantly greater gains in the mobilization arm by Week 8. Cervical rotation increased from 58 ± 9° to 82 ± 10° in the CSM group compared with 60 ± 8° to 70 ± 9° in the NMR group. The Week 8 between-group mean difference was 12.0° (95% CI: 7.5 to 16.5; p = 0.002) with a large effect size (d = 1.26), indicating superior rotation recovery with mobilization. Cervical flexion similarly increased from 46 ± 7° to 68 ± 9° in CSM compared with 47 ± 8° to 60 ± 8° in NMR, with a significant between-group mean difference of 8.0° (95% CI: 4.0 to 12.0; p = 0.01) and a large effect size (d = 0.94). These results support the biomechanical advantage of cervical mobilization for restoring cervical mobility, particularly in rotation and flexion.

DISCUSSION

This randomized controlled trial compared cervical spine mobilization and neuromuscular re-education for cervicogenic dizziness, demonstrating that both interventions produced meaningful improvements in pain intensity, balance performance, dizziness-related functional disability, and cervical mobility over eight weeks. Between-group comparisons showed a differential pattern of benefit, with mobilization producing greater reductions in neck pain and superior gains in cervical rotation and flexion, whereas neuromuscular re-education produced larger improvements in balance performance. These findings are clinically relevant because cervicogenic dizziness is typically multidimensional and may involve concurrent pain sensitization, motion restriction, and sensorimotor impairment, making it unlikely that a single intervention uniformly optimizes all outcomes. Contemporary syntheses of cervical-related dizziness trials support the role of manual therapy for improving dizziness impact and pain-related outcomes, while also recognizing that sensorimotor interventions are integral where balance and postural control deficits predominate (8).

The magnitude of pain reduction favored mobilization at Week 8, where the between-group difference was −1.20 VAS points with a large standardized effect size. This is consistent with the established neurophysiological and mechanical rationale for graded cervical mobilization, which can decrease pain, improve segmental mobility, and potentially normalize afferent signaling from cervical mechanoreceptors. Recent systematic review evidence indicates that manual therapy directed at the cervical region demonstrates statistically significant improvements in dizziness impact and intensity compared with placebo or control interventions in patients with cervical-related dizziness, supporting mobilization as an effective strategy for symptom modulation (8). Additionally, trials and secondary analyses in this population have reported meaningful improvements in cervical range of motion and postural function following cervical manual therapy, reinforcing the clinical plausibility of the present findings (9). Although this study did not directly assess proprioceptive accuracy or central sensorimotor integration, the observed improvements in pain and mobility with mobilization align with the broader evidence base that manual therapy can improve cervical kinematics and reduce symptom provocation during movement (8,9).

Balance outcomes significantly favored neuromuscular re-education, which demonstrated fewer BESS errors at Week 8 and a large effect size. This result is consistent with the theoretical and empirical premise that active sensorimotor training enhances postural control through targeted retraining of cervical proprioception and head–eye coordination, with progressive integration of balance tasks to improve stability and reduce movement-related disequilibrium. Recent clinical literature on cervicogenic dizziness and cervical-related dizziness increasingly highlights that exercise-based interventions, particularly those emphasizing sensorimotor control, may provide incremental benefit when dizziness and postural instability are prominent features, including improvements in balance and functional performance (10,11). Rehabilitation-oriented protocols and clinical pathways also emphasize that management of cervicogenic dizziness should not rely solely on manual techniques but should incorporate sensorimotor and vestibular-related exercises to restore postural and movement control, supporting the direction of effect observed in the present trial (11). Importantly, the balance advantage seen with neuromuscular re-education does not imply that manual therapy is ineffective for balance; rather, it suggests that balance recovery may require task-specific retraining that drives adaptive motor learning beyond what passive mobilization alone typically provides.

Functional disability as measured by DHI improved substantially in both groups, with mean scores decreasing to below 30 by Week 8, but without statistically significant between-group differences. This pattern suggests that both interventions reduced dizziness-related participation restrictions and symptom burden to a comparable degree, despite their differential effects on pain, mobility, and balance. This aligns with the multidomain nature of the DHI, which integrates physical, emotional, and functional impacts and may improve through multiple therapeutic pathways, including pain reduction, improved mobility, improved postural confidence, and education. The DHI remains widely used in dizziness research and is considered responsive for detecting meaningful changes in perceived handicap, although threshold values for minimal clinically important change vary by population and context (12). Given that both groups demonstrated large absolute reductions, the lack of between-group difference may reflect convergence of functional recovery once symptom burden decreases, or may reflect that DHI is influenced by broader factors (e.g., anxiety, avoidance behavior) not directly targeted differentially by these protocols.

From a clinical decision-making perspective, the present findings support a deficit-based approach to treatment selection. Patients presenting with prominent neck pain and restricted cervical mobility may benefit from mobilization-centered care early in rehabilitation, particularly when pain limits motion and contributes to symptom provocation during head movement. Conversely, patients demonstrating pronounced balance impairment, postural instability, or persistent disequilibrium may require structured neuromuscular re-education emphasizing proprioceptive retraining and balance tasks to optimize postural outcomes. The literature increasingly supports multimodal care in cervicogenic dizziness, where manual therapy combined with exercise-based sensorimotor rehabilitation can address complementary impairment domains and may yield broader improvements than either modality alone, although the comparative advantage of combined protocols requires direct testing (13,14). Therefore, while this trial did not include a combined-treatment arm, the differential outcome pattern provides a rational justification for staged or integrated rehabilitation strategies tailored to individual impairment profiles.

Several limitations should be considered when interpreting these findings. First, cervicogenic dizziness remains a diagnosis of exclusion, and although clinical criteria and exclusion screening were applied, advanced vestibular testing and imaging were not incorporated, which may introduce diagnostic heterogeneity and limit generalizability to subtypes of dizziness with mixed etiology (11,13). Second, therapist and participant blinding was not feasible, which may contribute to expectancy effects; however, assessor blinding mitigates detection bias for standardized outcomes. Third, follow-up was limited to eight weeks, and the durability of benefits beyond treatment completion remains uncertain. Finally, although multiple outcomes were reported to capture the multidimensional nature of cervicogenic dizziness, a prespecified primary endpoint and a formal multiplicity adjustment strategy would strengthen inferential robustness in future trials. Subsequent research should incorporate longer-term follow-up, combined-treatment arms, standardized diagnostic frameworks, and mechanistic outcomes such as proprioceptive joint position error or posturography to clarify pathways through which mobilization and neuromuscular re-education exert benefit.

CONCLUSION

Both cervical spine mobilization and neuromuscular re-education produced significant improvements in pain, balance, dizziness-related disability, and cervical mobility in adults with cervicogenic dizziness over eight weeks; however, mobilization demonstrated superior outcomes for pain reduction and cervical mobility, whereas neuromuscular re-education demonstrated superior improvements in balance performance, supporting a deficit-guided clinical approach in which manual therapy is prioritized for pain and motion restriction and sensorimotor training is emphasized for instability, with staged or integrated protocols potentially offering the most comprehensive functional recovery.

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