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COMPARATIVE EFFECTS OF NERVE FLOSSING AND DEEP NECK FLEXOR MUSCLE STRENGTHENING ON PAIN, RANGE OF MOTION AND FUNCTIONAL DISABILITY ON CERVICAL SPINAL STENOSIS

Original Research (ID: 1691)

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ABSTRACT

Background: Cervical spinal stenosis is a degenerative cervical spine disorder that may cause neck pain, restricted mobility, neurological symptoms, and functional limitation. Conservative physiotherapy is commonly recommended before surgical consideration, but the relative benefit of different exercise-based approaches remains unclear. Nerve flossing mainly targets neural mobility, whereas deep neck flexor strengthening focuses on cervical stability and postural control. Comparing these approaches may help guide more focused rehabilitation for patients with cervical spinal stenosis.

Objective: To compare the effects of nerve flossing and deep neck flexor strengthening on pain intensity, functional disability, and cervical range of motion in patients with cervical spinal stenosis.

Methods: This randomized controlled trial assessed 186 patients for eligibility, of whom 62 patients with imaging-confirmed cervical spinal stenosis were randomized into a nerve flossing group or a deep neck flexor strengthening group, with 31 participants in each group. After follow-up losses, 46 participants were included in the final analysis, including 22 in the nerve flossing group and 24 in the deep neck flexor strengthening group. Both groups received supervised treatment for 12 weeks, three sessions per week. Pain was assessed using the Visual Analogue Scale, functional disability using the Neck Disability Index, and cervical range of motion using an inclinometer at baseline, 6 weeks, and 12 weeks. Data were analyzed using mixed-design ANOVA.

Results: Both groups improved over time. VAS decreased from 7.19 ± 0.39 to 3.61 ± 0.22 in the nerve flossing group and from 7.20 ± 0.33 to 2.95 ± 0.41 in the deep neck flexor group, with a significant time × group interaction, $F(2,88) = 125.55$, $p < 0.001$. NDI decreased from 30.95 ± 2.68 to 17.36 ± 1.47 in the nerve flossing group and from 31.33 ± 2.50 to 13.04 ± 1.30 in the deep neck flexor group, $F(1.21,53.02) = 122.82$, $p < 0.001$. Significant time × group effects were also observed for cervical extension and left rotation, while flexion and right rotation improved comparably.

Conclusion: Both interventions improved pain, disability, and cervical mobility; however, deep neck flexor strengthening produced greater final improvement in pain and functional disability. It may be prioritized as a core rehabilitation strategy for cervical spinal stenosis, while nerve flossing may be considered as an adjunct for patients with neural symptoms.

Keywords: Cervical Vertebrae; Exercise Therapy; Neck Pain; Neural Mobilization; Range of Motion, Articular; Spinal Stenosis; Treatment Outcome

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INTRODUCTION

Cervical spinal stenosis is a clinically important degenerative condition in which narrowing of the cervical spinal canal or intervertebral foramina reduces the available space for the spinal cord and exiting nerve roots. This narrowing may occur due to disc degeneration, posterior disc protrusion, osteophyte formation, ligamentous hypertrophy, facet joint changes, trauma, tumors, or congenital canal narrowing. Although some individuals may remain asymptomatic, progressive compression of neural structures can lead to neck pain, radiating arm symptoms, reduced cervical mobility, sensory disturbance, weakness, and functional limitation (1,2). In adults, degenerative cervical changes commonly begin from the third and fourth decades of life and may gradually progress with age, making cervical spinal stenosis an increasingly relevant concern in routine physiotherapy and rehabilitation practice (3). Neck pain is one of the most frequent musculoskeletal complaints worldwide and can substantially affect quality of life, work productivity, sleep, mobility, and participation in daily activities. A considerable proportion of the population experiences cervical pain during life, and a smaller but clinically meaningful group develops persistent symptoms with disability (4,5). In cervical spinal stenosis, pain is not always related only to local tissue irritation; it may also arise from nerve root compression, altered cervical biomechanics, inflammation, reduced neural mobility, and impaired muscular control around the cervical spine. Patients may report pain localized to the neck or radiating toward the shoulder, arm, forearm, or hand, often accompanied by numbness, tingling, heaviness, weakness, or difficulty in performing fine motor tasks (6). These symptoms can limit cervical flexion, extension, rotation, and side bending, thereby interfering with activities such as driving, reading, working on computers, lifting objects, and maintaining prolonged postures (7).

The pathophysiology of cervical spinal stenosis is complex and usually involves both mechanical and neurological components. Degenerative disc disease may reduce disc height and promote posterior disc bulging, while osteophytes and thickened ligaments can further reduce the space available for the spinal cord and nerve roots (8). Foraminal narrowing may produce radicular symptoms, whereas central canal stenosis may place the spinal cord at risk of progressive neurological compromise. However, clinical presentation does not always match imaging severity, as some patients with marked radiological stenosis may have mild symptoms, while others with modest imaging findings may experience significant pain and disability (9). This highlights the importance of evaluating cervical spinal stenosis through a combined clinical and functional approach rather than relying on imaging alone. Magnetic resonance imaging is commonly used to confirm canal narrowing and identify contributing structures, but functional assessment remains essential for determining the patient's actual limitations and rehabilitation needs (10). Conservative management is usually considered before surgical intervention, particularly in patients without severe or progressive neurological deficits. Common non-operative approaches include medication, education, activity modification, manual therapy, traction, therapeutic exercise, postural correction, neural mobilization, and targeted strengthening of cervical stabilizing muscles (11). Physiotherapy plays a central role because it addresses modifiable impairments such as pain, restricted mobility, altered posture, neural mechanosensitivity, weakness, and reduced functional capacity. However, the most appropriate conservative intervention for cervical spinal stenosis remains uncertain, especially when symptoms arise from both neural compression and impaired cervical muscular control (12).

Nerve flossing, also described as neural gliding or neurodynamic mobilization, is a therapeutic technique designed to restore the normal movement of peripheral nerves relative to surrounding tissues. The nervous system is a continuous and mobile structure that must glide smoothly during limb and spinal movement. When a nerve becomes mechanically sensitive or restricted due to compression, inflammation, adhesions, or altered tissue mobility, patients may develop pain, paresthesia, and movement-related symptoms. Nerve flossing uses controlled movements that alternately tension and slacken the nerve pathway, aiming to improve intraneural circulation, reduce mechanosensitivity, enhance axoplasmic flow, and decrease symptoms associated with nerve irritation (13,14). In cervical radiculopathy and cervicobrachial pain, neural mobilization has shown beneficial effects on pain, disability, cervical mobility, and upper limb function, although the magnitude of benefit varies across studies and patient populations (15,16). Deep neck flexor muscle strengthening represents another important conservative strategy for cervical disorders. The deep cervical flexors, particularly the longus colli and longus capitis, contribute to segmental stability, postural control, and maintenance of cervical alignment. In patients with chronic neck pain, these muscles often show reduced activation, poor endurance, and delayed neuromuscular control, while superficial muscles such as the sternocleidomastoid and anterior scalene may become overactive as compensatory stabilizers (17). This imbalance can increase mechanical load on cervical joints, disturb posture, reduce movement efficiency, and contribute to recurrent pain. Training the deep neck flexors through controlled craniocervical flexion and progressive strengthening exercises has been reported to reduce pain, improve postural alignment, enhance neuromuscular control, and decrease disability in several neck pain populations (18,19).

Although both nerve flossing and deep neck flexor strengthening are clinically relevant, they target different mechanisms. Nerve flossing primarily addresses neural mobility, mechanosensitivity, and nerve-related symptoms, while deep neck flexor strengthening focuses on cervical stability, muscular endurance, postural correction, and movement control. Cervical spinal stenosis may involve both neural compromise and mechanical dysfunction; therefore, either approach may provide meaningful improvement. However, direct

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comparative evidence between these two interventions in patients with cervical spinal stenosis is limited. Most available studies have focused on cervical radiculopathy, nonspecific neck pain, cervicobrachial pain, or cervical spondylosis, rather than radiologically or clinically diagnosed cervical spinal stenosis. As a result, it remains unclear whether a neural mobility-based approach or a deep stabilizer strengthening approach produces greater improvement in pain, cervical range of motion, and functional disability in this specific population (20,21). This gap is clinically important because patients with cervical spinal stenosis frequently present with persistent symptoms that affect daily function and may increase the risk of long-term disability if not managed appropriately. Identifying the more effective physiotherapy intervention can help clinicians design focused, evidence-informed rehabilitation programs and may reduce unnecessary treatment variation. The research question of the present study is whether nerve flossing or deep neck flexor muscle strengthening is more effective in reducing pain, improving cervical range of motion, and decreasing functional disability in patients with cervical spinal stenosis. It is hypothesized that there will be a difference between the effects of nerve flossing and deep neck flexor muscle strengthening on these clinical outcomes. Therefore, the objective of the present study is to compare the effects of nerve flossing and deep neck flexor muscle strengthening on pain, cervical range of motion, and functional disability in patients with cervical spinal stenosis.

METHODS

This randomized clinical trial was conducted to compare the effects of nerve flossing and deep neck flexor muscle strengthening on pain intensity, cervical range of motion, and functional disability in patients with cervical spinal stenosis. The trial was registered as NCT07604935, and data were collected from Sukoon Rehab Center and Physiotherapy Clinic, Lahore. The study was completed over a period of nine months after approval of the synopsis by the relevant research board. Ethical approval was obtained from the Ethical Committee of Green International University. All participants were informed about the purpose of the study, treatment procedures, possible benefits, potential discomfort, voluntary participation, confidentiality of data, and their right to withdraw from the study at any stage without any negative consequence. Written informed consent was obtained from all eligible participants before baseline assessment and intervention. The sample size was calculated using the Visual Analogue Scale as the primary outcome measure for pain. A two-group comparison was planned with a 5% level of significance, 80% statistical power, an expected clinically meaningful difference of 1.6 points on the VAS, and an estimated standard deviation of 2.0. Based on the formula for comparison of two independent means, the required sample size was 25 participants per group. After adjusting for an anticipated 20% dropout rate, the final sample size was increased to 31 participants per group, making a total of 62 participants. According to the CONSORT flow, 186 participants were assessed for eligibility. Of these, 124 were excluded, including 80 who did not meet the inclusion criteria and 44 who declined to participate. The remaining 62 participants were randomized into two equal groups, with 31 participants allocated to Group A and 31 to Group B. In Group A, 5 participants were lost to follow-up and 4 discontinued the intervention, leaving 22 participants for final analysis. In Group B, 4 participants were lost to follow-up and 3 discontinued the intervention, leaving 24 participants for final analysis. Thus, the final analysis was performed on 46 participants.

Participants were recruited using non-probability purposive sampling according to predefined eligibility criteria. Adult male and female patients aged 20–50 years were included if they had a clinical and radiological diagnosis of cervical spinal stenosis confirmed by MRI, cervical pain with or without radiation to the upper limb, at least one neurological sign such as sensory disturbance, muscle weakness, or diminished reflexes, symptoms persisting for more than four weeks but less than six months, the ability to understand and follow exercise instructions, and a baseline VAS pain score of at least 3 out of 10. Patients were excluded if they had a history of cervical spine surgery, recent trauma, fracture, cervical instability, surgically treated disc herniation, peripheral neuropathy, thoracic outlet syndrome, rheumatoid arthritis, pregnancy, or recent use of medication that could affect nerve function, such as systemic steroids. After screening and consent, baseline demographic and clinical data were collected before the start of treatment. Participants were then randomly allocated into Group A, which received nerve flossing, and Group B, which received deep neck flexor strengthening. Both groups received supervised treatment three sessions per week for 12 weeks, with each session lasting approximately 45 minutes. Before the specific intervention, all participants received a standardized preparatory session consisting of 10 minutes of heat therapy to the cervical region, postural education, ergonomic advice for sitting, sleeping, desk work, and mobile phone use, followed by gentle active range of motion exercises of the neck and shoulders within a pain-free range. This common baseline management was used to reduce stiffness, prepare the cervical region for exercise, and maintain consistency between groups.

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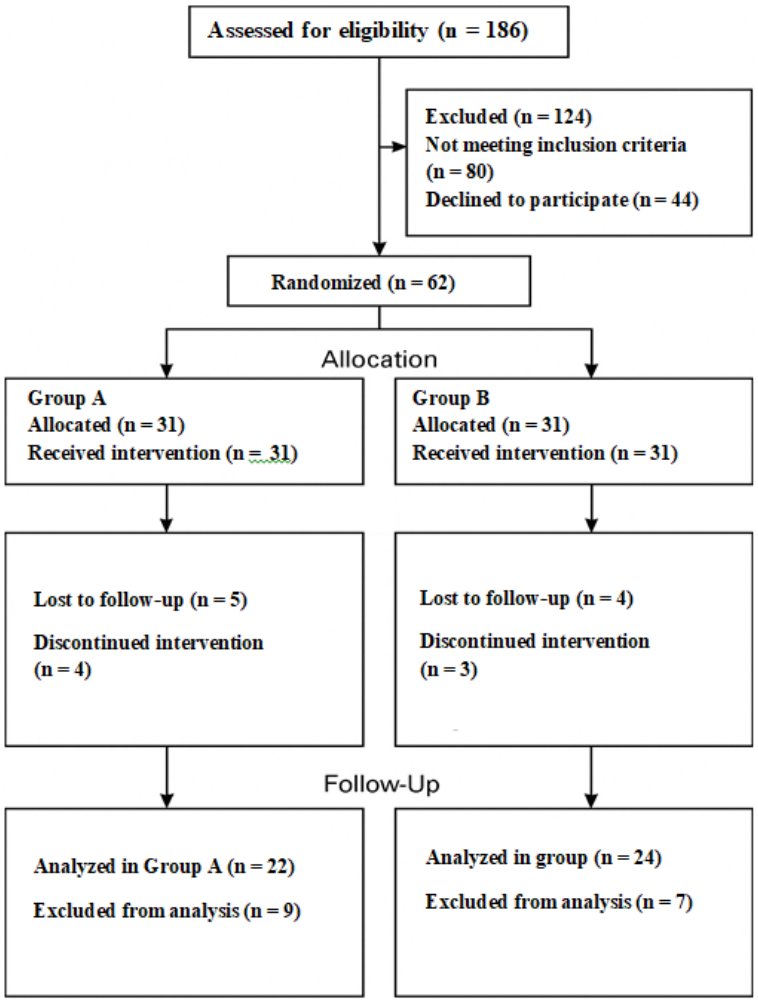
Participants in Group A received cervical nerve flossing exercises directed toward the involved neural structures. The intervention included gentle sliding and tensioning movements for the median, ulnar, and radial nerves, performed within the participant's symptom tolerance. Each exercise was performed in three sets of 10 repetitions, with progression based on improved movement range, smoother coordination, and tolerance without aggravation of neurological symptoms. The technique was performed rhythmically and carefully, with attention to avoiding excessive neural tension or symptom provocation. Participants in Group B received a structured deep neck flexor strengthening program, including supine chin tucks, chin tucks with head lift, sitting chin tucks, and quadruped cervical stabilization exercises. Each exercise was performed in three sets of 10 repetitions, with isometric holds of approximately 5–10 seconds according to tolerance. Progression was based on improved endurance, better neuromuscular control, transition from supported to functional positions, and reduced overactivity of superficial cervical muscles. At the end of each session, both groups performed 5–10 minutes of gentle stretching of the neck and shoulder region. Participant compliance, pain response, neurological symptoms, and any adverse effects were monitored throughout the intervention period. The primary and secondary outcomes were assessed at baseline, 6 weeks, and 12 weeks using standardized clinical tools. Pain intensity was measured using the Visual Analogue Scale, which consists of a 10 cm line anchored by "no pain" at one end and "worst possible pain" at the other. Functional disability was measured using the Neck Disability Index, a 10-item questionnaire assessing the impact of neck symptoms on daily activities such as personal care, lifting, reading, concentration, work, driving, sleep, and recreation. Cervical range of motion was measured using an inclinometer in flexion, extension, right and left lateral flexion, and right and left rotation. Measurements were recorded on standardized data collection sheets, and all information was stored securely with access limited to authorized members of the research team.

Data were analyzed using IBM SPSS Statistics version 25.0. Before the main analysis, data were screened for missing values and outliers. The Shapiro-Wilk test was used to assess normality, while Levene's test was applied to examine homogeneity of variance between groups. Descriptive statistics, including mean and standard deviation, were calculated for demographic characteristics and outcome variables at baseline, 6 weeks, and 12 weeks. To compare the effects of nerve flossing and deep neck flexor strengthening over time, a 2 × 3 mixed-design analysis of variance with repeated measures was applied. In this model, group served as the between-subjects factor, while time served as the within-subjects factor. The main effects of time and group, along with the time × group interaction, were examined for VAS, NDI, and cervical range of motion in all measured directions. Mauchly's test was used to assess sphericity, and the Greenhouse-Geisser correction was planned where this assumption was violated. Partial eta squared was calculated to determine effect size, with values of 0.01, 0.06, and 0.14 interpreted as small, medium, and large effects, respectively. The level of statistical significance was set at $p < 0.05$ for all analyses.

Figure 1 CONSORT Diagram



RESULTS

A total of 186 participants were assessed for eligibility. Of these, 124 were excluded, including 80 who did not meet the inclusion criteria and 44 who declined to participate. The remaining 62 participants were randomized equally into the nerve flossing group and the deep neck flexor strengthening group, with 31 participants allocated to each group. During the study period, 5 participants were lost to follow-

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up and 4 discontinued treatment in the nerve flossing group, while 4 participants were lost to follow-up and 3 discontinued treatment in the deep neck flexor strengthening group. The final analysis was therefore conducted on 46 participants, including 22 in the nerve flossing group and 24 in the deep neck flexor strengthening group. The baseline demographic and clinical characteristics were comparable between the two groups. The mean age was 35.95 ± 7.17 years in the nerve flossing group and 36.21 ± 7.19 years in the deep neck flexor strengthening group ($p = 0.905$). The mean BMI was 24.14 ± 2.16 kg/m² in the nerve flossing group and 24.25 ± 2.18 kg/m² in the deep neck flexor strengthening group ($p = 0.860$). Symptom duration was reported as 9.27 ± 4.90 weeks in the nerve flossing group and 10.00 ± 5.19 weeks in the deep neck flexor strengthening group ($p = 0.628$). Gender distribution was equal in both groups, with 11 males and 11 females in the nerve flossing group and 12 males and 12 females in the deep neck flexor strengthening group ($p = 1.000$). The affected side was also similarly distributed between groups, with right-sided involvement in 8 participants in each group, left-sided involvement in 7 participants in the nerve flossing group and 8 participants in the deep neck flexor strengthening group, and bilateral involvement in 7 and 8 participants, respectively ($p = 0.977$). Occupational distribution was not significantly different between groups using an exact test approach because most expected cell counts were below 5 ($p = 0.976$).

Baseline outcome values were also comparable between groups. The baseline VAS score was 7.19 ± 0.39 in the nerve flossing group and 7.20 ± 0.33 in the deep neck flexor strengthening group ($p = 0.925$). The baseline Neck Disability Index score was 30.95 ± 2.68 and 31.33 ± 2.50, respectively ($p = 0.621$). Baseline cervical flexion was 35.05 ± 1.76° in the nerve flossing group and 35.17 ± 1.90° in the deep neck flexor strengthening group ($p = 0.826$). Baseline extension was 48.55 ± 2.09° and 48.87 ± 2.58°, respectively ($p = 0.648$). Baseline left rotation was 58.45 ± 2.20° and 58.87 ± 2.58° ($p = 0.557$), while baseline right rotation was 59.55 ± 2.09° and 59.87 ± 2.58° ($p = 0.648$). Pain intensity decreased in both groups over the 12-week intervention period. In the nerve flossing group, the mean VAS score decreased from 7.19 ± 0.39 at baseline to 4.35 ± 0.28 at 6 weeks and 3.61 ± 0.22 at 12 weeks. In the deep neck flexor strengthening group, the mean VAS score decreased from 7.20 ± 0.33 at baseline to 5.03 ± 0.23 at 6 weeks and 2.95 ± 0.41 at 12 weeks. The total mean reduction in VAS score from baseline to 12 weeks was 3.58 points in the nerve flossing group and 4.25 points in the deep neck flexor strengthening group.

Mixed-design ANOVA showed a statistically significant main effect of time for VAS scores, $F(2, 88) = 4425.05$, $p < 0.001$, $\eta^2p = 0.990$. The time × group interaction was also statistically significant, $F(2, 88) = 125.55$, $p < 0.001$, $\eta^2p = 0.740$. At 6 weeks, the nerve flossing group had a lower mean VAS score than the deep neck flexor strengthening group. At 12 weeks, the deep neck flexor strengthening group had a lower mean VAS score than the nerve flossing group. Functional disability also decreased over time in both groups. In the nerve flossing group, the mean Neck Disability Index score decreased from 30.95 ± 2.68 at baseline to 21.77 ± 1.93 at 6 weeks and 17.36 ± 1.47 at 12 weeks. In the deep neck flexor strengthening group, the mean score decreased from 31.33 ± 2.50 at baseline to 22.67 ± 1.90 at 6 weeks and 13.04 ± 1.30 at 12 weeks. The total mean reduction in Neck Disability Index score from baseline to 12 weeks was 13.59 points in the nerve flossing group and 18.29 points in the deep neck flexor strengthening group.

For Neck Disability Index scores, mixed-design ANOVA with Greenhouse-Geisser correction showed a statistically significant main effect of time, $F(1.21, 53.02) = 3796.08$, $p < 0.001$, $\eta^2p = 0.990$. The time × group interaction was also statistically significant, $F(1.21, 53.02) = 122.82$, $p < 0.001$, $\eta^2p = 0.740$. At the final assessment, the deep neck flexor strengthening group had a lower mean disability score than the nerve flossing group. Cervical range of motion improved in all reported directions in both groups. Cervical flexion increased from 35.05 ± 1.76° at baseline to 41.05 ± 1.76° at 6 weeks and 45.59 ± 1.37° at 12 weeks in the nerve flossing group. In the deep neck flexor strengthening group, flexion increased from 35.17 ± 1.90° at baseline to 41.04 ± 1.97° at 6 weeks and 45.92 ± 1.79° at 12 weeks. The main effect of time was statistically significant for flexion, $F(2, 88) = 7091.68$, $p < 0.001$, $\eta^2p = 0.990$, while the time × group interaction was not statistically significant, $F(2, 88) = 1.72$, $p = 0.184$, $\eta^2p = 0.040$.

Cervical extension increased from 48.55 ± 2.09° at baseline to 53.55 ± 2.09° at 6 weeks and 56.91 ± 1.72° at 12 weeks in the nerve flossing group. In the deep neck flexor strengthening group, extension increased from 48.87 ± 2.58° to 53.87 ± 2.58° and 58.08 ± 2.34° across the same assessment points. The main effect of time was statistically significant, $F(2, 88) = 6178.86$, $p < 0.001$, $\eta^2p = 0.990$. The time × group interaction was also statistically significant, $F(2, 88) = 18.92$, $p < 0.001$, $\eta^2p = 0.300$. Left cervical rotation increased from 58.45 ± 2.20° at baseline to 64.55 ± 2.09° at 6 weeks and 68.95 ± 1.70° at 12 weeks in the nerve flossing group. In the deep neck flexor strengthening group, left rotation increased from 58.87 ± 2.58° to 64.75 ± 2.64° and 69.75 ± 2.56°, respectively. The main effect of time was statistically significant, $F(2, 88) = 6453.86$, $p < 0.001$, $\eta^2p = 0.990$. The time × group interaction was also statistically significant, $F(2, 88) = 5.03$, $p = 0.009$, $\eta^2p = 0.100$.

Right cervical rotation increased from 59.55 ± 2.09° at baseline to 65.55 ± 2.09° at 6 weeks and 69.95 ± 1.70° at 12 weeks in the nerve flossing group. In the deep neck flexor strengthening group, right rotation increased from 59.87 ± 2.58° to 65.75 ± 2.64° and 70.33 ± 2.96° across the same time points. The main effect of time was statistically significant, $F(2, 88) = 1424.48$, $p < 0.001$, $\eta^2p = 0.970$. The time × group interaction was not statistically significant, $F(2, 88) = 0.11$, $p = 0.901$, $\eta^2p = 0.002$. Overall, both interventions showed measurable improvements in pain intensity, functional disability, and cervical range of motion over 12 weeks. Significant time × group interactions were observed for VAS, Neck Disability Index, cervical extension, and left cervical rotation. No statistically significant time × group interaction was found for cervical flexion or right cervical rotation.

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Table 1. Baseline demographic and clinical characteristics of participants

Variable	Nerve Flossing (n = 22)	DNF Strengthening (n = 24)	p-value
Age (years)	35.95 ± 7.17	36.21 ± 7.19	0.905
BMI (kg/m²)	24.14 ± 2.16	24.25 ± 2.18	0.860
Symptom duration (weeks)	9.27 ± 4.90	10.00 ± 5.19	0.628
Male	11 (50.0%)	12 (50.0%)	1.000
Female	11 (50.0%)	12 (50.0%)	
Right side affected	8 (36.4%)	8 (33.3%)	0.977
Left side affected	7 (31.8%)	8 (33.3%)	
Bilateral involvement	7 (31.8%)	8 (33.3%)	
Desk job	6 (27.3%)	5 (20.8%)	0.976*
Teacher	4 (18.2%)	4 (16.7%)	
Driver	4 (18.2%)	4 (16.7%)	
Manual worker	3 (13.6%)	3 (12.5%)	
Nurse	2 (9.1%)	4 (16.7%)	
Student	3 (13.6%)	4 (16.7%)	

Table 2. Pain intensity and functional disability outcomes across treatment duration

Outcome	Time point	Nerve Flossing (n = 22)	DNF Strengthening (n = 24)	Mean change NF	Mean change DNF	Time effect	Time × Group effect
VAS pain score	Baseline	7.19 ± 0.39	7.20 ± 0.33	—	—	$F(2,88) = 4425.05$, $p < 0.001$, $\eta^2p = 0.990$	$F(2,88) = 125.55$, $p < 0.001$, $\eta^2p = 0.740$
	6 weeks	4.35 ± 0.28	5.03 ± 0.23	-2.84	-2.17		
	12 weeks	3.61 ± 0.22	2.95 ± 0.41	-3.58	-4.25		
Neck Disability Index	Baseline	30.95 ± 2.68	31.33 ± 2.50	—	—	$F(1.21,53.02) = 3796.08$, $p < 0.001$, $\eta^2p = 0.990$	$F(1.21,53.02) = 122.82$, $p < 0.001$, $\eta^2p = 0.740$
	6 weeks	21.77 ± 1.93	22.67 ± 1.90	-9.18	-8.66		
	12 weeks	17.36 ± 1.47	13.04 ± 1.30	-13.59	-18.29		

Table 3. Cervical range of motion outcomes across treatment duration

Motion	Time point	Nerve Flossing (n = 22)	DNF Strengthening (n = 24)	Mean change NF	Mean change DNF	Time effect	Time × Group effect
Flexion	Baseline	35.05 ± 1.76	35.17 ± 1.90	—	—	$F(2,88) = 7091.68$, $p < 0.001$, $\eta^2p = 0.990$	$F(2,88) = 1.72$, $p = 0.184$, $\eta^2p = 0.040$
	6 weeks	41.05 ± 1.76	41.04 ± 1.97	+6.00	+5.87		
	12 weeks	45.59 ± 1.37	45.92 ± 1.79	+10.54	+10.75		
Extension	Baseline	48.55 ± 2.09	48.87 ± 2.58	—	—	$F(2,88) = 6178.86$, $p < 0.001$, $\eta^2p = 0.990$	$F(2,88) = 18.92$, $p < 0.001$, $\eta^2p = 0.300$
	6 weeks	53.55 ± 2.09	53.87 ± 2.58	+5.00	+5.00		
	12 weeks	56.91 ± 1.72	58.08 ± 2.34	+8.36	+9.21		

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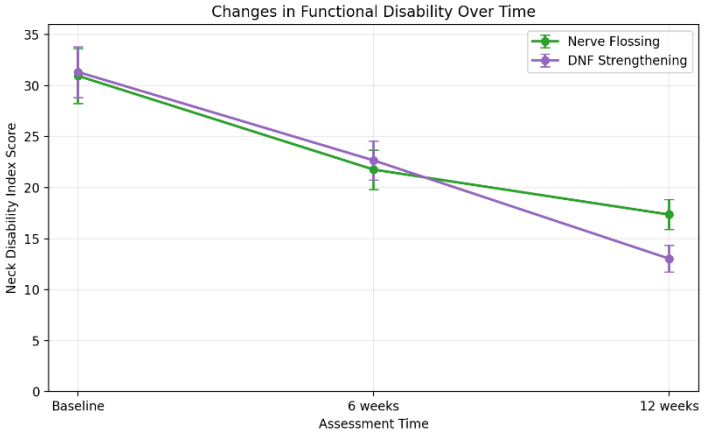
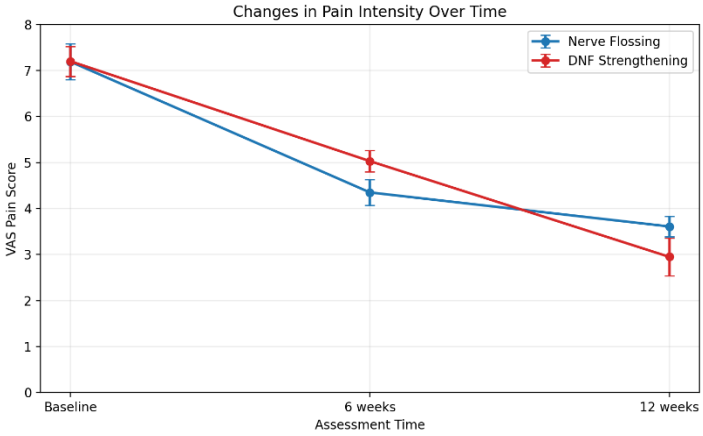
Left rotation	Baseline	58.45 ± 2.20	58.87 ± 2.58	—	—	$F(2,88) = 6453.86$, $p < 0.001$, $\eta^2p = 0.990$	$F(2,88) = 5.03$, $p = 0.009$, $\eta^2p = 0.100$
	6 weeks	64.55 ± 2.09	64.75 ± 2.64	+6.10	+5.88		
	12 weeks	68.95 ± 1.70	69.75 ± 2.56	+10.50	+10.88		
Right rotation	Baseline	59.55 ± 2.09	59.87 ± 2.58	—	—	$F(2,88) = 1424.48$, $p < 0.001$, $\eta^2p = 0.970$	$F(2,88) = 0.11$, $p = 0.901$, $\eta^2p = 0.002$
	6 weeks	65.55 ± 2.09	65.75 ± 2.64	+6.00	+5.88		
	12 weeks	69.95 ± 1.70	70.33 ± 2.96	+10.40	+10.46		





DISCUSSION

The present randomized clinical trial compared the effects of nerve flossing and deep neck flexor strengthening on pain intensity, functional disability, and cervical range of motion in patients with cervical spinal stenosis. The findings showed that both interventions produced measurable improvement over the 12-week treatment period; however, the pattern and magnitude of improvement differed between groups. Pain intensity, Neck Disability Index scores, and cervical range of motion improved significantly over time in both groups, indicating that both nerve flossing and deep neck flexor strengthening had therapeutic value in the conservative management of cervical spinal stenosis. The time × group interaction was significant for VAS, NDI, cervical extension, and left cervical rotation, whereas flexion and right rotation improved similarly in both groups. Pain intensity decreased in both treatment groups, but the final improvement was greater in the deep neck flexor strengthening group. The VAS score decreased from 7.19 ± 0.39 to 3.61 ± 0.22 in the nerve flossing group, while it decreased from 7.20 ± 0.33 to 2.95 ± 0.41 in the deep neck flexor strengthening group. This finding suggested that both interventions reduced pain, but deep neck flexor strengthening produced a more favorable pain outcome by the end of treatment. The significant time × group interaction for VAS supported that the two interventions did not follow the same pattern of change over time. Interestingly, the nerve flossing group showed a lower pain score at 6 weeks, whereas the deep neck flexor strengthening group showed a lower pain score at 12 weeks. This pattern may indicate that nerve flossing provided earlier symptomatic relief through reduced neural mechanosensitivity, while deep neck flexor strengthening required a longer training period to produce more stable improvement through postural control, muscular endurance, and segmental stabilization.

These pain-related findings were consistent with earlier work showing that neural mobilization can reduce pain in patients with cervical radiculopathy, cervicobrachial pain, and neck-related neural symptoms (22, 23). Nerve flossing may improve symptoms by promoting neural sliding, reducing intraneural pressure, improving axoplasmic flow, and decreasing sensitivity of irritated neural structures (24). However, cervical spinal stenosis is not only a neurodynamic problem; it also involves structural narrowing, altered cervical mechanics, postural dysfunction, and muscular control deficits. This may explain why nerve flossing improved pain but did not provide the same final pain reduction as deep neck flexor strengthening. The present findings also agreed with studies reporting that deep cervical flexor training reduces neck pain by improving neuromuscular control, reducing overactivity of superficial cervical muscles, and restoring better cervical alignment (25-27). Functional disability also improved in both groups, with a larger reduction in the deep neck flexor strengthening group. The Neck Disability Index score decreased from 30.95 ± 2.68 to 17.36 ± 1.47 in the nerve flossing group and from 31.33 ± 2.50 to 13.04 ± 1.30 in the deep neck flexor strengthening group. The reduction was 13.59 points in the nerve flossing group and 18.29 points in the deep neck flexor strengthening group. Since both reductions exceeded the commonly cited clinically meaningful change of approximately 10 points, both interventions appeared clinically useful; however, the greater improvement in the deep neck flexor strengthening group indicated a stronger functional effect. This finding was important because disability in cervical spinal stenosis

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is usually influenced not only by pain but also by reduced endurance, fear of movement, postural fatigue, difficulty maintaining sustained positions, and limitations in daily activities such as reading, driving, computer work, lifting, and sleeping.

The greater reduction in disability after deep neck flexor strengthening may be explained by the stabilizing function of the longus colli and longus capitis muscles. These muscles support the cervical spine at a segmental level and help maintain a neutral craniocervical posture during functional activities. In patients with chronic neck pain and degenerative cervical conditions, deep cervical flexor activity is often reduced, while superficial muscles such as the sternocleidomastoid and anterior scalene become overactive as compensatory stabilizers (28,29). This altered recruitment pattern may increase cervical loading and contribute to recurrent pain and disability. By improving deep flexor activation and endurance, the strengthening protocol may have reduced excessive superficial muscle activity and improved postural efficiency. Previous studies have similarly reported that deep cervical flexor training improves disability, posture, muscle endurance, and functional performance in patients with neck pain and cervical dysfunction (12, 21). Cervical range of motion improved in all reported directions in both groups. Flexion improved from 35.05 ± 1.76° to 45.59 ± 1.37° in the nerve flossing group and from 35.17 ± 1.90° to 45.92 ± 1.79° in the deep neck flexor strengthening group. The time effect was significant, but the time × group interaction was not significant, indicating comparable improvement in flexion. Right rotation also improved similarly between groups, increasing from 59.55 ± 2.09° to 69.95 ± 1.70° in the nerve flossing group and from 59.87 ± 2.58° to 70.33 ± 2.96° in the deep neck flexor strengthening group. These findings suggested that both interventions were effective in improving general cervical mobility in these directions, likely through pain reduction, improved movement confidence, and repeated supervised exercise.

In contrast, extension and left rotation demonstrated significant time × group interactions. Cervical extension increased from 48.55 ± 2.09° to 56.91 ± 1.72° in the nerve flossing group and from 48.87 ± 2.58° to 58.08 ± 2.34° in the deep neck flexor strengthening group. Left rotation increased from 58.45 ± 2.20° to 68.95 ± 1.70° in the nerve flossing group and from 58.87 ± 2.58° to 69.75 ± 2.56° in the deep neck flexor strengthening group. These differences favored the deep neck flexor strengthening group. Extension is often clinically sensitive in cervical stenosis because it may reduce the available space within the cervical canal and neural foramina, making patients more guarded during this movement (18). Improved extension tolerance in the deep neck flexor group may therefore reflect better movement control, reduced protective muscle guarding, and improved confidence during cervical motion. This finding aligned with previous evidence indicating that targeted deep cervical flexor training can improve cervical mobility and functional movement control (12, 30). The findings also supported the view that cervical spinal stenosis should be managed through a broader rehabilitation model rather than a purely symptom-based or neurodynamic approach. Nerve flossing appeared useful, particularly for improving pain and mobility, but deep neck flexor strengthening produced greater final improvement in pain, disability, extension, and left rotation. This did not reduce the clinical value of nerve flossing; rather, it suggested that nerve flossing may be more suitable as an adjunct intervention, especially in patients with radiating symptoms, neural mechanosensitivity, or positive neurodynamic signs. Deep neck flexor strengthening, on the other hand, appeared more directly related to the mechanical and postural impairments that commonly accompany cervical stenosis. A combined approach may therefore have potential value, but the present study compared the two interventions separately and did not test their combined effect.

One strength of this study was its randomized comparative design, which allowed a direct comparison between two commonly used physiotherapy interventions. Another strength was the use of standardized outcome measures, including VAS for pain, NDI for disability, and inclinometer-based assessment of cervical range of motion. The inclusion of repeated measurements at baseline, 6 weeks, and 12 weeks also allowed the pattern of change over time to be examined rather than relying only on pre- and post-treatment differences. The study further focused on cervical spinal stenosis, a population in which comparative evidence for specific conservative physiotherapy strategies remains limited. Several limitations were also present. The final analyzed sample included 46 participants rather than the originally randomized 62 participants, and the analysis appeared to be based on participants who completed follow-up. This may have reduced statistical power and may also have introduced attrition bias. An intention-to-treat analysis would have strengthened the findings by preserving the original randomization. The study also did not report stratification according to the radiological severity, level, or type of stenosis. Patients with mild foraminal stenosis may respond differently from those with severe central canal stenosis or multilevel compression, and this variation may influence treatment response (11, 24). Another limitation was the absence of long-term follow-up, which made it unclear whether the observed improvements were sustained after completion of the supervised intervention.

The outcome measures were clinically relevant but limited. Pain, disability, and range of motion provided useful information about patient progress, but additional objective measures such as the craniocervical flexion test with pressure biofeedback, deep neck flexor endurance testing, electromyography, hand grip strength, upper limb neurodynamic testing, sensory examination, reflex grading, or functional performance tests could have provided a more complete picture of neuromuscular and neurological recovery (9, 20). The study also did not clearly report adverse events, analgesic use, home exercise adherence, or co-interventions, all of which may influence treatment outcomes. Participant blinding was not feasible because of the nature of exercise-based interventions, although assessor blinding should be maintained wherever possible in similar trials. Future studies should include larger multicenter samples, longer follow-up periods, and intention-to-treat analysis to improve the reliability and generalizability of findings. Radiological grading of stenosis should be incorporated to determine whether treatment response differs according to stenosis severity, involved spinal level, or central versus foraminal narrowing. Future trials should also examine whether combining nerve flossing with deep neck flexor

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strengthening provides superior outcomes compared with either intervention alone. Additional objective measures of cervical muscle function, neurodynamic sensitivity, upper limb function, and quality of life would help clarify the mechanisms behind clinical improvement. Despite these limitations, the present findings suggested that both nerve flossing and deep neck flexor strengthening were beneficial for patients with cervical spinal stenosis, with deep neck flexor strengthening showing greater final improvement in pain, disability, cervical extension, and left cervical rotation over 12 weeks.

CONCLUSION

The present study concluded that both nerve flossing and deep neck flexor strengthening were effective conservative interventions for improving pain, functional disability, and cervical mobility in patients with cervical spinal stenosis. However, deep neck flexor strengthening produced greater overall improvement, particularly in reducing pain and disability and enhancing cervical movement control. These findings suggest that restoring deep cervical muscle function, postural stability, and segmental control may be more beneficial than addressing neural mobility alone in this patient population. Therefore, deep neck flexor strengthening should be considered an important component of physiotherapy rehabilitation for cervical spinal stenosis, while nerve flossing may still be useful as an adjunct intervention in patients with neural symptoms. The study adds practical evidence for clinicians by supporting a focused, exercise-based approach that targets the underlying functional impairments commonly associated with cervical spinal stenosis.

AUTHOR CONTRIBUTION

Author	Contribution
Akasha Khan	Conceptualization, Methodology, Formal Analysis, Writing - Original Draft, Validation, Supervision
Dr. Komal Tehzeeb	Methodology, Investigation, Data Curation, Writing - Review & Editing
Prof Dr Fahad Tanveer	Investigation, Data Curation, Formal Analysis, Software
Dr. Izzah Ijaz Syed	Software, Validation, Writing - Original Draft
Dr. Sehrish Shahzad	Formal Analysis, Writing - Review & Editing
Muhammad Hammad Khan	Writing - Review & Editing, Assistance with Data Curation

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