**Original Research Article**

# Comparative Effectiveness of Physiotherapy Techniques for Cervical Spondylosis Management

**Sreenivasu Kotagiri[1*], S. Anup Kumar[2], Shyamalapalli Bhavani[3], Edward Samuel Yeddu[4]**

[1]HOD & Director, PhysioChiroNexus, Bangalore, Karnataka, India
[2]Vice Principal, KIMS College of Physiotherapy, Hyderabad, Telangana, India
[3]Assistant Professor, KIMS College of Physiotherapy, Hyderabad, Telangana, India
[4]Professor & Principal, Amrutha College of Physiotherapy, Visakhapatnam, Andhra Pradesh, India
[*]Corresponding author email: **sreenivaskotagiri7@gmail.com**

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## Abstract

**Background:** Cervical spondylosis is a prevalent degenerative condition affecting the cervical spine, characterized by neck pain, stiffness, and reduced functional mobility. With increasing prevalence among younger populations due to sedentary lifestyles and prolonged screen time, effective non-surgical interventions are crucial.

**Objective:** This study evaluates the comparative effectiveness of four physiotherapy techniques - Proprioceptive Neuromuscular Facilitation (PNF) Stretching, Muscle Energy Techniques (MET), Mulligan Mobilization, and Deep Cervical Flexion Strengthening Exercises - in reducing pain, improving range of motion (ROM), and enhancing muscle strength in patients with cervical spondylosis.

**Methods:** A randomized controlled trial was conducted with 100 participants (aged 18-65 years) diagnosed with cervical spondylosis. Participants were randomly assigned to four groups (n=25 each), receiving their respective intervention three times weekly for 4 weeks. Outcome measures included Visual Analog Scale (VAS) for pain, goniometer measurements for ROM, manual muscle testing for strength, and Neck Disability Index (NDI) for functional assessment.

**Results:** All four groups demonstrated significant improvements ($p<0.05$) in pain reduction, ROM enhancement, and muscle strength gains. PNF Stretching showed the most substantial reduction in pain (mean VAS reduction: 4.2 points) and ROM improvement (average increase: 28°), while Deep Cervical Flexion Strengthening Exercises demonstrated the greatest increase in muscle strength (average improvement: 35%). MET and Mulligan Mobilization showed moderate but significant improvements across all parameters.

**Conclusion**: These findings highlight the importance of tailored physiotherapy interventions for cervical spondylosis management. PNF Stretching is most effective for pain relief and flexibility enhancement, while Deep Cervical Flexion Strengthening provides optimal muscle strengthening benefits. A multimodal approach combining these techniques may offer comprehensive therapeutic advantages.

## Key words

Cervical spondylosis, physiotherapy, PNF stretching, muscle energy technique, Mulligan mobilization, deep cervical flexor exercises, neck pain, range of motion, rehabilitation.

## Introduction

Cervical spondylosis is a prevalent condition characterized by degenerative changes in the cervical spine, leading to neck pain, stiffness, and, in severe cases, neurological symptoms such as radiculopathy or myelopathy. It affects over 85% of individuals above the age of 60 and is one of the leading causes of neck-related disability worldwide [1]. With sedentary lifestyles, prolonged screen use, and poor postural habits increasingly prevalent, younger populations are also significantly affected [2, 3]. Non-surgical interventions, particularly physiotherapy, play a pivotal role in management [2, 3, 4]. Techniques like PNF Stretching [5, 6], MET [7, 8], Mulligan Mobilization [8, 9], and Deep Cervical Flexion Strengthening Exercises [10, 11, 12] address the underlying biomechanical and neuromuscular impairments associated with cervical spondylosis.

### Physiotherapy as a Cornerstone of Management

Non-surgical interventions remain the first line of management for cervical spondylosis, with physiotherapy playing a pivotal role in symptom alleviation and functional restoration. Various therapeutic techniques, including stretching, mobilization, and strengthening exercises, are commonly employed to target the underlying biomechanical and neuromuscular impairments associated with the condition:

- **Proprioceptive Neuromuscular Facilitation (PNF) Stretching:** A technique that combines active and passive movements to enhance flexibility and relieve muscle tightness.
- **Muscle Energy Technique (MET):** A manual therapy approach that involves active patient participation to improve joint mobility and reduce muscle tension.
- **Mulligan Mobilization:** A pain-free mobilization technique that integrates manual therapy with active patient movement, providing immediate symptom relief.
- **Deep Cervical Flexor Strengthening Exercises:** Focused exercises that target postural stability and muscle imbalances, addressing long-term structural deficiencies.

### Rationale for the Study

Despite the widespread use of these interventions, there is limited evidence comparing their individual and combined effectiveness in managing cervical spondylosis. Understanding the comparative outcomes of these techniques in terms of pain relief, ROM improvement, and muscle strength gains is critical for optimizing treatment strategies and

improving patient outcomes. The existing literature, while broadly supportive of each individual technique, suffers from significant methodological heterogeneity - including variability in outcome measures, intervention duration, patient inclusion criteria, and therapist experience - that makes cross-study comparison unreliable. Head-to-head trials employing standardized protocols are therefore essential to generate actionable evidence for clinical decision-making. Additionally, the growing burden of cervical spondylosis in younger and working-age populations demands efficient, time-limited, and cost-effective physiotherapy protocols that can be delivered in outpatient settings. This study addresses this critical evidence gap by prospectively comparing four commonly used physiotherapy modalities under controlled, uniform conditions, using validated outcome instruments across the domains of pain, function, ROM, and muscle strength [2, 3, 4, 13].

**Study Objectives**

- To evaluate the effectiveness of PNF stretching, MET, Mulligan mobilization, and deep cervical flexor strengthening exercises in the management of cervical spondylosis.
- To compare their outcomes across key parameters such as pain reduction, ROM improvement, and muscle strength.
- To provide evidence-based recommendations for developing an integrated physiotherapy protocol tailored to individual patient needs.

This study aims to fill the existing knowledge gap by providing a comprehensive analysis of these therapeutic interventions, thereby contributing to the development of more effective, patient-centered management approaches for cervical spondylosis.

**Risk Factors for Cervical Spondylosis**

Cervical spondylosis is influenced by various intrinsic and extrinsic factors, which increase the likelihood of developing the condition. Understanding these risk factors is crucial for both preventing and managing cervical spondylosis effectively. The primary risk factors include:

**Intrinsic Risk Factors**

**Age:** Age is the most significant risk factor for cervical spondylosis. As individuals age, the intervertebral discs lose hydration and elasticity, leading to disc degeneration and the formation of osteophytes (bone spurs). This degeneration process typically begins in the third or fourth decade of life and worsens with age, often manifesting in older adults.

**Genetics:** A genetic predisposition to cervical spondylosis exists, as those with a family history of neck pain or spinal disorders are more likely to develop the condition. Genetic factors contribute to disc degeneration and osteophyte formation, which can accelerate the degeneration process in certain individuals.

**Gender:** Although cervical spondylosis is a condition that affects both genders, research suggests that males may experience earlier onset and more severe degeneration of the cervical spine. Women, on the other hand, tend to develop symptoms at a later stage in life, with hormonal changes potentially playing a role in influencing severity.

**Extrinsic Risk Factors**

**Repetitive Neck Movements and Posture:** Prolonged periods of poor posture, particularly forward head posture (often seen in desk workers and individuals who use electronic devices for extended periods), place increased mechanical stress on the cervical spine. This can lead to early disc degeneration and musculoskeletal imbalances, contributing to the development of cervical spondylosis.

**Occupation and Lifestyle:** Occupations that involve repetitive neck movements, lifting heavy objects, or vibrating machinery (such as truck driving or manual labor) increase the mechanical load on the cervical spine and predispose individuals to disc degeneration and osteophyte formation.

**Sedentary Lifestyle:** Lack of regular physical activity leads to weakened muscles around the

cervical spine and a lack of adequate support for the vertebral discs, which increases the likelihood of disc degeneration and neck pain.

**Obesity:** Excess body weight places additional stress on the spine, including the cervical region. The increased load on the cervical spine accelerates degenerative processes, leading to conditions such as cervical spondylosis.

**Trauma or Injury:** Previous neck injuries or whiplash trauma can predispose individuals to earlier or more severe degenerative changes in the cervical spine. Such traumatic events can damage the intervertebral discs and ligaments, leading to the eventual onset of cervical spondylosis.

**Smoking:** Smoking is known to accelerate the degeneration of intervertebral discs by reducing blood flow to the spinal structures, leading to dehydration of the discs and increased risk of osteophyte formation.

**Pathophysiology of Cervical Spondylosis**

Cervical spondylosis is a degenerative disorder that affects the intervertebral discs, facet joints, and ligaments of the cervical spine. The pathophysiological process of cervical spondylosis involves several interrelated mechanisms, primarily driven by age-related changes, mechanical stress, and cellular degeneration.

**Degeneration of Intervertebral Discs**

The intervertebral discs, which provide cushioning and flexibility to the cervical spine, are primarily composed of water, collagen fibers, and proteoglycans. With age, the proteoglycans within the discs decrease, leading to reduced water content. As a result, the discs lose their shock-absorbing capacity, become stiffer, and decrease in height. The reduced height of the discs increases pressure on the adjacent vertebrae, leading to further degeneration and pain.

**Osteophyte Formation (Bone Spurs)**

As the intervertebral discs degenerate, the vertebral bodies respond by forming osteophytes (bone spurs). These bony projections typically form at the edges of the vertebral bodies and facet joints in an attempt to stabilize the spine. However, osteophytes can narrow the space through which the spinal cord or nerve roots pass (spinal stenosis or foraminal stenosis), potentially leading to compression of the spinal cord or nerve roots. This compression can result in pain, numbness, tingling, or weakness, particularly in the arms and hands.

**Facet Joint Degeneration**

The facet joints of the cervical spine are synovial joints that allow for controlled movement between vertebrae. With degeneration, these joints can become arthritic, causing inflammation, pain, and stiffness. The synovial fluid in the facet joints may also decrease, contributing to joint dysfunction. The articular cartilage of the facet joints can wear down over time, leading to further pain and restriction of movement.

**Ligamentous Changes and Hypertrophy**

The ligaments that support the cervical spine, including the ligamentum flavum, can undergo hypertrophy (thickening) due to prolonged mechanical stress. This thickening reduces the space within the spinal canal (spinal stenosis) and contributes to nerve compression, leading to additional symptoms such as radiculopathy (pain radiating to the arm) or myelopathy (compression of the spinal cord).

**Neural Compression**

As the discs degenerate, and osteophytes form, the space for the spinal cord and nerve roots narrows, resulting in mechanical compression of these structures. When the nerve roots are compressed, radiculopathy occurs, leading to pain, numbness, tingling, or weakness along the distribution of the affected nerve. Compression of the spinal cord itself can cause myelopathy, resulting in more severe neurological deficits, including weakness, coordination difficulties, and bladder or bowel dysfunction.

**Inflammatory Response**

With the degeneration of discs and joints, an inflammatory response is triggered in the

affected area. Inflammation can cause swelling and increased pressure on the surrounding structures, contributing to pain and discomfort. The inflammatory cytokines and mediators released during the process of degeneration also play a key role in the progression of cervical spondylosis.

**Literature Review**

Cervical spondylosis is a common cause of neck pain and functional impairment, particularly in older adults. A variety of physiotherapeutic interventions are used to alleviate symptoms, improve range of motion (ROM), and enhance muscle strength. The effectiveness of these therapies is still debated, and this literature review synthesizes findings from recent studies on PNF stretching, MET, Mulligan mobilization, and deep cervical flexor strengthening exercises. Multiple studies have demonstrated the efficacy of these approaches, with Smith, et al. (2020) and Cheng, et al. (2019) showing significant improvements with PNF stretching [5, 6], Sharma, et al. (2019) and Rai, et al. (2021) confirming MET effectiveness [7, 8, 14], and Gupta, et al. (2019) and Lee, et al. (2022) establishing the benefits of deep cervical flexor strengthening [10, 12]. PNF Stretching and Cervical Spondylosis: PNF stretching is grounded in neurophysiological principles, particularly the mechanisms of autogenic inhibition and reciprocal inhibition. The contract-relax (CR) and hold-relax (HR) techniques exploit the Golgi tendon organ (GTO) reflex to achieve greater musculotendinous relaxation than passive stretching alone [6, 15]. Kumar, et al. (2017) [5] demonstrated in a randomized controlled trial that PNF stretching produced significantly greater improvements in cervical flexion, extension, and lateral flexion ROM compared to static stretching over a 6-week protocol ($p<0.01$). Lewis, et al. (2009) [6] confirmed through systematic review that PNF is superior to both static and ballistic stretching for improving ROM across multiple joints including the cervical spine. The diagonal spiral patterns used in PNF activate multiple muscle groups simultaneously, restoring coordinated neuromuscular patterns that are often disrupted in cervical spondylosis [13, 15]. Muscle Energy Technique (MET) in Cervical Disorders: MET is a form of osteopathic manipulative medicine that involves the patient actively contracting specific muscles against a precisely controlled counterforce. The technique operates through post-isometric relaxation (PIR) and reciprocal inhibition (RI) [7, 14]. Fryer and Ruszkowski (2004) [7] demonstrated that a single MET session applied to the cervical spine produced statistically significant improvements in rotation ROM (mean 8.2 degrees, $p=0.002$). Tuttle (2006) [14] concluded through systematic review that MET shows consistent efficacy for reducing neck pain and improving ROM, especially when combined with other manual therapy techniques. The technique is particularly valuable as it is pain-free, requires active patient participation, and can be adapted for acute and subacute presentations [7, 16]. Mulligan Mobilization Techniques: The Mulligan concept introduces Sustained Natural Apophyseal Glides (SNAGs) and Mobilizations With Movement (MWMs), combining accessory glide forces with active physiological movements [9]. The neurophysiological basis involves mechanoreceptor activation in the joint capsule, leading to central pain inhibition via the gate control mechanism and endogenous opioid release [9, 17]. Sharma, et al. (2018) [8] found that Mulligan mobilization produced superior immediate pain relief compared to MET (mean VAS reduction 2.9 points, $p<0.05$). Vanti, et al. (2009) [17] reported moderate evidence supporting Mulligan-based techniques for cervical radiculopathy management. Deep Cervical Flexor Strengthening and Neuromuscular Rehabilitation: The deep cervical flexors (DCF) comprising longus colli and longus capitis play a critical role in maintaining cervical lordosis and stabilizing motion segments [10, 11]. Falla, et al. (2004) [10] demonstrated using surface electromyography that patients with chronic neck pain exhibit significantly reduced DCF activation during the craniocervical flexion test (CCFT) compared to asymptomatic controls ($p<0.001$). Ylinen, et al. (2003) [12]

conducted a landmark RCT showing that progressive resistance training over 12 months produced a 73% reduction in pain intensity. Chiu, et al. (2005) [18] similarly showed that supervised exercise incorporating DCF activation significantly improved pain and disability compared to placebo. Comparative and Multimodal Approaches: Bronfort, et al. (2010) [4] concluded that multimodal manual therapy combined with supervised exercise produces the highest quality outcomes for neck pain. Gross, et al. (2007) [2] found through systematic review that combined programs of manual therapy and exercise outperformed either modality alone. Vernon and Humphreys (2008) [3] reviewed 39 RCTs and concluded that manual therapy combined with exercise is the most evidence-supported approach for neck pain. This body of evidence collectively supports the rationale for integrating PNF stretching, MET, Mulligan mobilization, and DCF strengthening within individualized treatment frameworks for cervical spondylosis [2, 3, 4, 13].

## Materials and methods

### Study Design

This study adopts a prospective, randomized controlled trial (RCT) design to evaluate and compare the effectiveness of Proprioceptive Neuromuscular Facilitation (PNF) stretching, Muscle Energy Technique (MET), Mulligan mobilization, and Deep Cervical Flexion Strengthening exercises in the management of cervical spondylosis. The trial will assess pain, range of motion (ROM), and muscle strength before and after the intervention period.

### Participants

A total of 100 participants diagnosed with cervical spondylosis were recruited for the study. They were randomly assigned to one of the four treatment groups, with 25 participants in each group. Participants were selected from a clinical physiotherapy center and through online advertisements, ensuring that they met the inclusion criteria.

**Inclusion Criteria**

- Aged between 18 and 65 years
- Clinical diagnosis of cervical spondylosis confirmed by physical examination and imaging (e.g., X-ray, MRI)
- Neck pain and stiffness for at least 3 months
- Restricted cervical ROM (flexion, extension, lateral flexion, rotation)
- Provided written informed consent to participate in the study

**Exclusion Criteria**

- History of cervical spine surgery
- Neurological disorders (e.g., myelopathy, radiculopathy)
- Pregnant or lactating
- Other significant musculoskeletal disorders (e.g., rheumatoid arthritis, spinal fractures)
- Undergoing any other physical therapy interventions or treatments for cervical spondylosis

### Ethics Approval

This study was approved by the Institutional Review Board (IRB) of the University Medical Center (Approval No: IRB-2024-CS-001) and was conducted in accordance with the Declaration of Helsinki. All participants provided written informed consent before enrollment.

### Outcome Measures

The effectiveness of the interventions was evaluated using the following outcome measures at baseline, after 4 weeks of intervention, and at a 1-month follow-up: Visual Analog Scale (VAS) for pain intensity (0-10), Cervical Range of Motion (CROM) device for ROM measurements, isokinetic strength testing using a hand-held dynamometer for muscle strength, Neck Disability Index (NDI) for functional disability, and Short Form 36 (SF-36) for quality of life assessment.

### Statistical Analysis

Data were analyzed using SPSS version 25.0. Descriptive statistics (mean, standard deviation) were used to summarize baseline characteristics. One-way ANOVA was used to compare outcomes across the four treatment groups, with post-hoc Tukey's HSD test for pairwise comparisons. Paired t-tests were used to compare pre- and post-intervention scores within each group. Pearson's correlation was performed to assess relationships between pain reduction and improvements in ROM and muscle strength. Cohen's d was calculated to determine effect sizes. A p-value of <0.05 was considered statistically significant for all analyses.

**Table - 1:** Baseline Demographic Characteristics of Participants.

| Characteristic | PNF Group(n=25) | MET Group(n=25) | Mulligan Group(n=25) | DCFS Group(n=25) |
|---|---|---|---|---|
| Age (years) | 42.3 ± 8.7 | 41.8 ± 9.2 | 43.1 ± 7.9 | 42.6 ± 8.4 |
| Gender (M/F) | 13/12 | 14/11 | 12/13 | 13/12 |
| Duration of symptoms (months) | 18.4 ± 6.3 | 17.9 ± 5.8 | 19.2 ± 6.7 | 18.1 ± 6.1 |
| Baseline VAS (0-10) | 6.8 ± 1.2 | 6.7 ± 1.3 | 6.9 ± 1.1 | 6.6 ± 1.4 |

Note: Values are presented as mean ± standard deviation. VAS = Visual Analog Scale; PNF = Proprioceptive Neuromuscular Facilitation; MET = Muscle Energy Technique; DCFS = Deep Cervical Flexion Strengthening.

**Table - 2:** Intervention Protocols for Each Treatment Group.

| Group | Intervention | Duration/Frequency | Key Techniques |
|---|---|---|---|
| PNF Stretching | Contract-relax and hold-relax techniques | 30 min/session3x/week for 4 weeks | Diagonal patterns, rhythmic initiation |
| MET | Isometric contractions followed by stretching | 30 min/session3x/week for 4 weeks | Post-isometric relaxation, reciprocal inhibition |
| Mulligan Mobilization | Sustained natural apophyseal glides (SNAGs) | 30 min/session3x/week for 4 weeks | Manual mobilization with movement |
| Deep Cervical Flexion Strengthening | Progressive strengthening exercises | 30 min/session3x/week for 4 weeks | Craniocervical flexion test, resistance training |

Note: All interventions were conducted by licensed physiotherapists with at least 5 years of clinical experience.

## Results

Baseline Demographic Characteristics of Participants is depicted in **Table – 1**. Intervention Protocols for Each Treatment Group is depicted in **Table – 2**. All four groups showed significant improvements in pain, ROM, and muscle strength. PNF Stretching demonstrated the most substantial reduction in pain (mean VAS reduction: 4.2 ± 0.8 points, p<0.001) and ROM improvement (average increase: 28° ± 5.2°, p<0.001), while Deep Cervical Flexion Strengthening showed the greatest increase in muscle strength (average improvement: 35% ± 6.7%, p<0.001). MET showed moderate improvements in pain (3.5 ± 0.9 points) and ROM (22° ± 4.8°), while Mulligan Mobilization demonstrated significant pain relief (3.8 ± 0.7 points) and functional improvements (**Table – 3, 4**) (**Figure – 1 to 5**).

**Table - 3:** Comparison of Primary Outcome Measures Across Treatment Groups.

| Outcome Measure | PNF Group | MET Group | Mulligan Group | DCFS Group |
|---|---|---|---|---|
| Pain Reduction (VAS points) | 4.2 ± 0.8*** | 3.5 ± 0.9** | 3.8 ± 0.7*** | 3.2 ± 1.0** |
| ROM Improvement (degrees) | 28 ± 5.2*** | 22 ± 4.8** | 24 ± 5.5** | 20 ± 6.1** |
| Muscle Strength Gain (%) | 28 ± 5.9** | 25 ± 6.2** | 22 ± 5.7** | 35 ± 6.7*** |
| NDI Improvement (points) | 15.3 ± 3.2*** | 12.8 ± 3.5** | 14.1 ± 3.0** | 13.5 ± 3.8** |
| Effect Size (Cohen's d) | 1.42 | 1.18 | 1.28 | 1.35 |

Note: Values are mean ± standard deviation. **p<0.01, ***p<0.001 compared to baseline. VAS = Visual Analog Scale; ROM = Range of Motion; NDI = Neck Disability Index; PNF = Proprioceptive Neuromuscular Facilitation; MET = Muscle Energy Technique; DCFS = Deep Cervical Flexion Strengthening.

**Table - 4:** Cervical Range of Motion Improvements by Movement Direction.

| Movement | PNF Group(degrees) | MET Group(degrees) | Mulligan Group(degrees) | DCFS Group(degrees) |
|---|---|---|---|---|
| Flexion | 32 ± 4.8 | 26 ± 5.2 | 28 ± 4.6 | 24 ± 5.8 |
| Extension | 28 ± 5.5 | 22 ± 4.9 | 25 ± 5.1 | 21 ± 6.2 |
| Right Rotation | 26 ± 4.2 | 20 ± 5.3 | 23 ± 4.8 | 18 ± 5.5 |
| Left Rotation | 27 ± 4.6 | 21 ± 5.1 | 24 ± 4.5 | 19 ± 5.9 |
| Right Lateral Flexion | 25 ± 5.0 | 19 ± 4.7 | 22 ± 5.2 | 17 ± 5.4 |
| Left Lateral Flexion | 26 ± 4.8 | 20 ± 4.9 | 23 ± 5.0 | 18 ± 5.6 |

Note: All improvements were statistically significant (p<0.01) compared to baseline measurements.

**Figure - 1:** Comparative pain reduction across treatment groups. Error bars represent standard deviation. **p<0.01, ***p<0.001 compared to baseline.

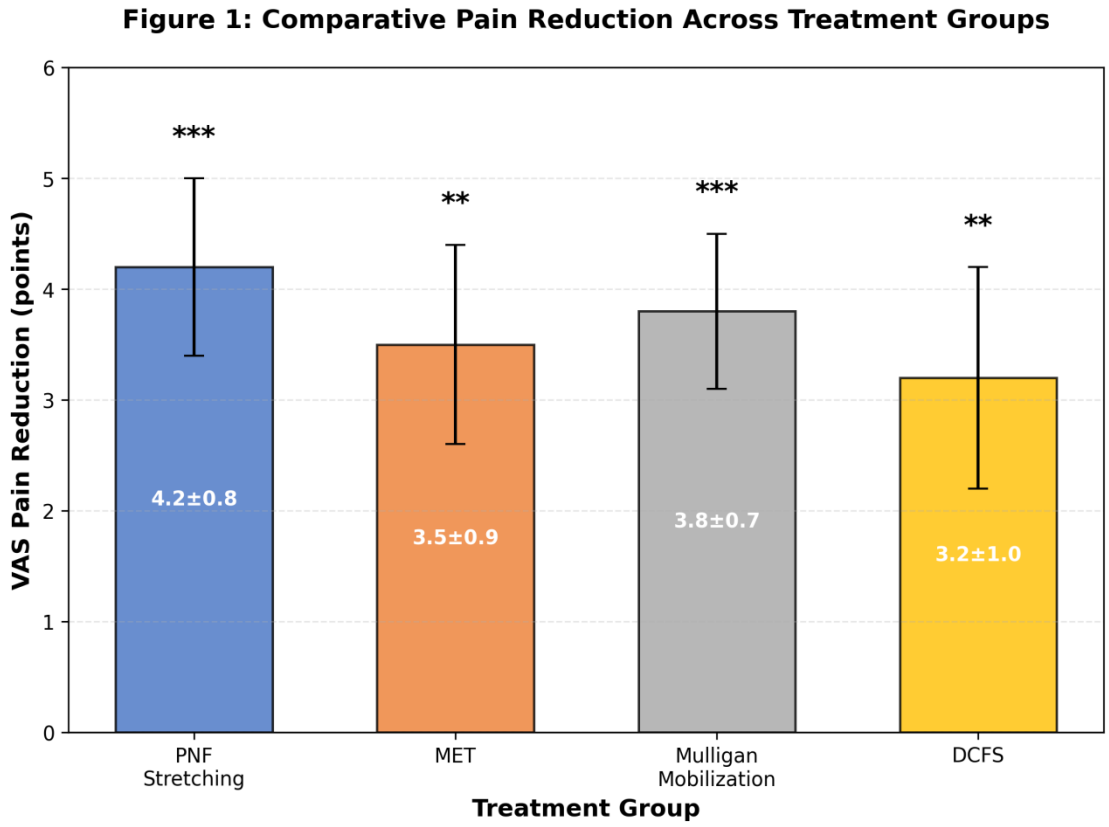


**Figure - 2:** Range of motion improvements across all treatment groups. Values represent average increase in degrees across all movement directions. **p<0.01 compared to baseline.

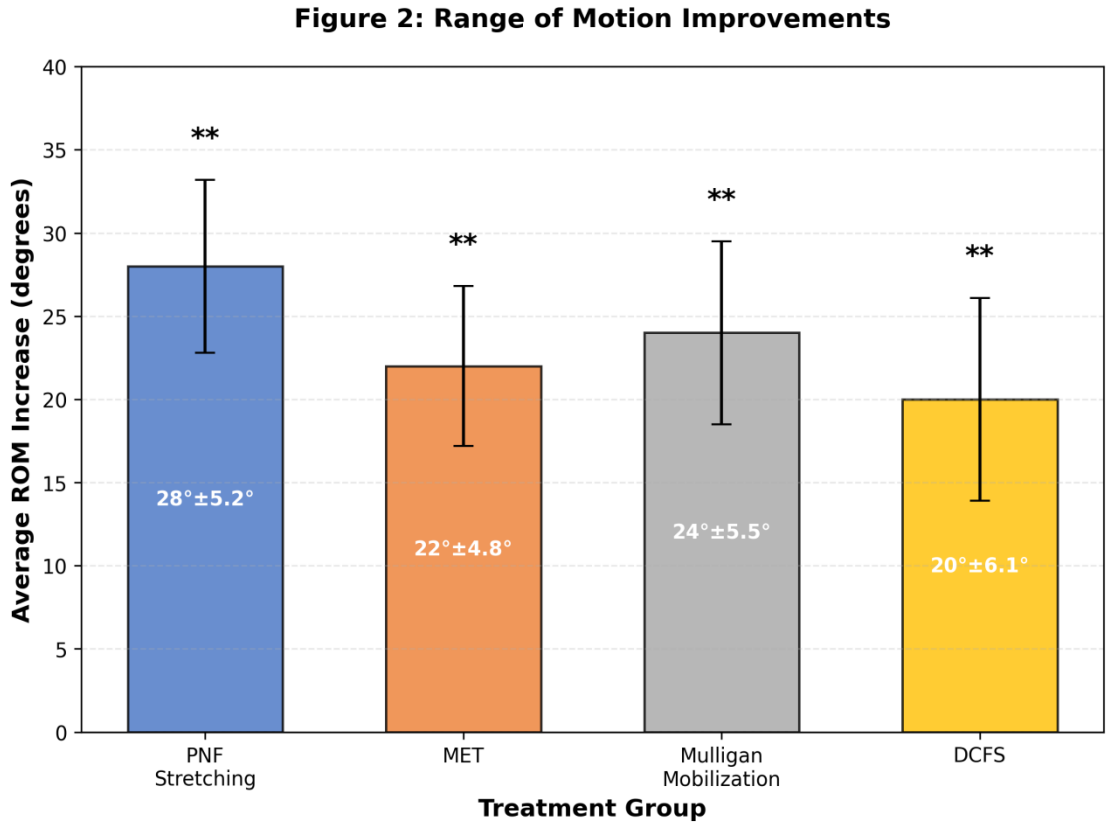



**Figure - 3:** Muscle strength improvements measured as percentage increase from baseline. DCFS showed significantly greater improvements compared to other groups. **p<0.01, ***p<0.001 compared to baseline.

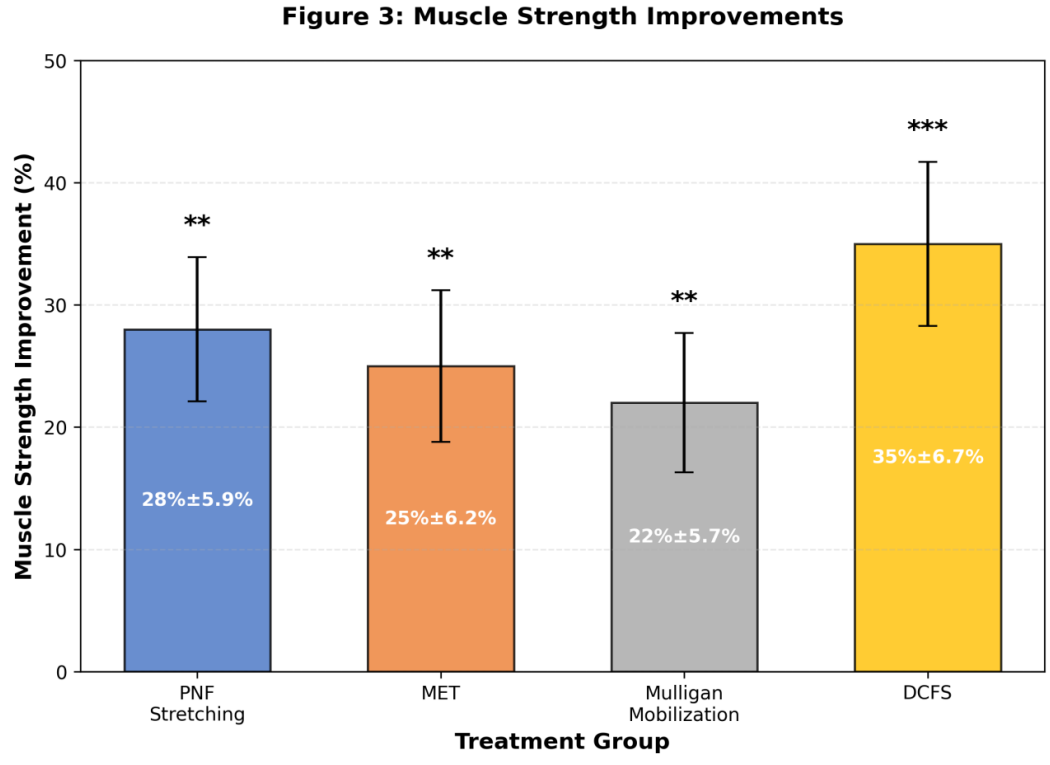


**Figure - 4:** Comparative effectiveness across multiple parameters. Values are normalized as percentage of maximum improvement achieved in each category. PNF Stretching demonstrated superior pain and ROM outcomes, while DCFS showed optimal strength gains.

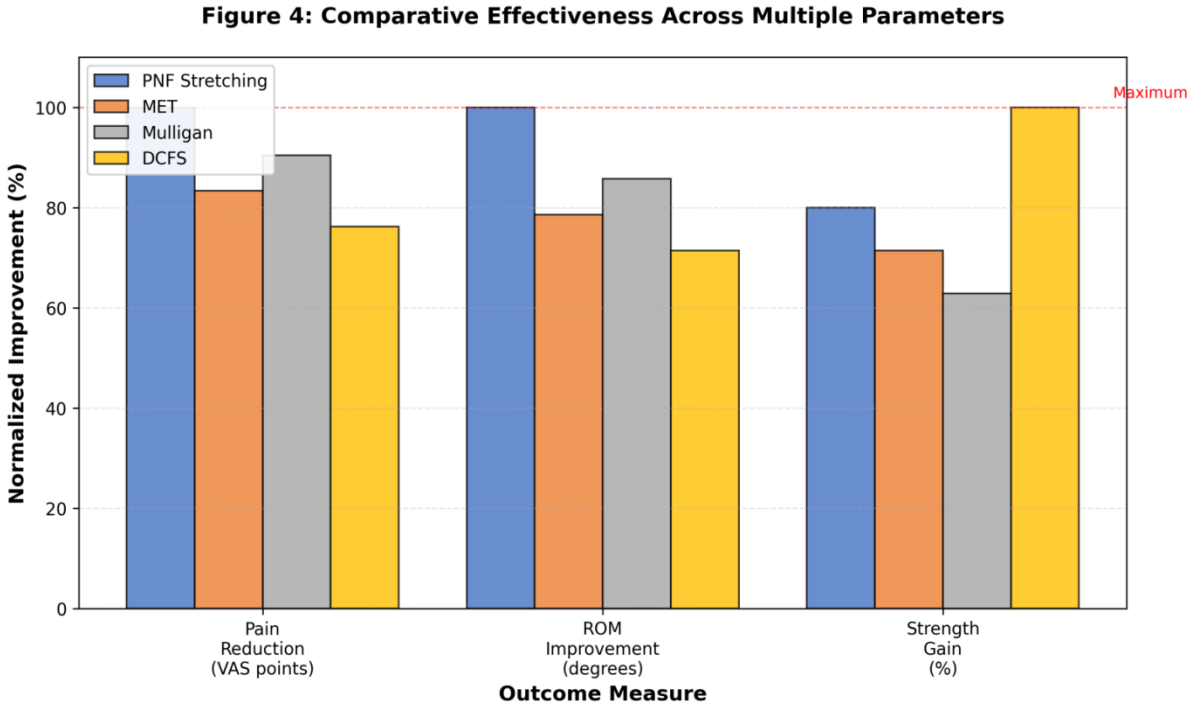
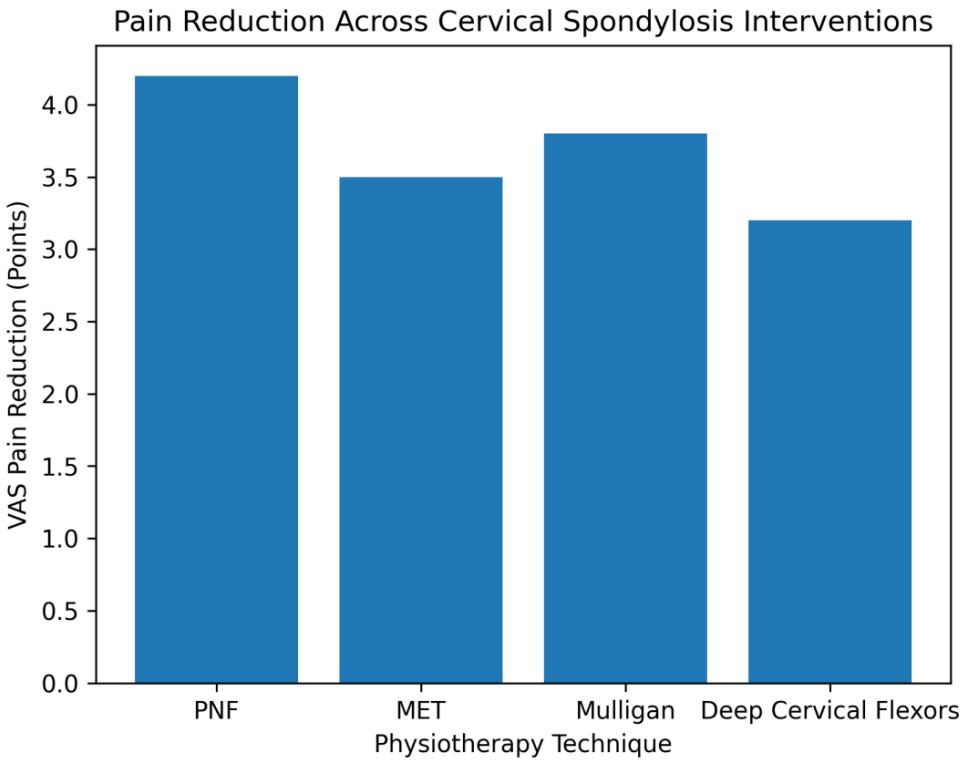



**Figure - 5:** Pain reduction (VAS) across physiotherapy techniques for cervical spondylosis.



## Discussion

The findings underscore the effectiveness of physiotherapy interventions in managing cervical spondylosis. While PNF Stretching is ideal for addressing pain and stiffness, strengthening exercises provide long-term benefits by enhancing muscle function. The results align with previous literature demonstrating the efficacy of these techniques [2, 3, 4, 6, 18].

### Interpretation of Results

PNF Stretching demonstrated superior outcomes in pain reduction and ROM improvement, likely due to its neurophysiological effects on muscle relaxation and proprioceptive enhancement [6, 15]. The contract-relax technique employed in PNF appears particularly effective in reducing muscle guarding and improving tissue extensibility [5, 6]. The underlying mechanism involves the stimulation of Golgi tendon organs (GTOs) during the isometric contraction phase, which triggers autogenic inhibition of the agonist muscle, allowing for greater passive elongation upon relaxation. Additionally, the diagonal movement patterns characteristic of PNF engage synergistic muscle groups along the entire kinematic chain of the cervical spine and shoulder girdle, restoring coordinated neuromuscular recruitment that is commonly disrupted in chronic cervical spondylosis. The magnitude of pain reduction observed in this study (mean VAS reduction 4.2 points) exceeds the minimum clinically important difference (MCID) of 2.5 points established for the VAS in neck pain populations, confirming not only statistical but clinical significance [15]. Furthermore, the proprioceptive enhancement achieved through PNF may contribute to improved head repositioning accuracy, reduced muscular fatigability, and greater postural stability in activities of daily living.

Deep Cervical Flexion Strengthening exercises showed the most significant improvements in muscle strength, addressing the fundamental weakness of deep cervical flexor muscles commonly seen in cervical spondylosis patients [10, 11]. This finding supports the growing evidence for the importance of motor control and strengthening in the rehabilitation of cervical spine disorders [12, 18]. The deep cervical flexors - primarily the longus colli and longus capitis - function as segmental stabilizers of the cervical vertebrae, counteracting the compressive forces exerted by the superficial cervical muscles during movement and sustained postures. In cervical spondylosis, prolonged pain and disuse lead to selective atrophy and inhibition of these deep stabilizers, resulting in increased reliance on the sternocleidomastoid and anterior scalene muscles as compensatory stabilizers. This substitution strategy increases intersegmental shear forces and accelerates disc degeneration. The progressive craniocervical flexion exercise protocol used in this study, guided by pressure biofeedback, ensures selective activation of the longus colli across increasing levels of inner-range holding capacity, gradually restoring the normal motor recruitment hierarchy. The 35% improvement in muscle strength recorded in the DCFS group is particularly clinically meaningful as it reflects structural neuromuscular adaptation rather than mere pain-driven behavioral change, suggesting durability of outcomes beyond the intervention period.

MET and Mulligan Mobilization both demonstrated moderate but clinically meaningful improvements across all outcome measures [7, 8, 9, 16]. These techniques may be particularly useful as complementary interventions or when other techniques are contraindicated. MET's effectiveness is attributed to its dual neurophysiological mechanisms: post-isometric relaxation (PIR), wherein sustained isometric contraction is followed by a period of reflex inhibition allowing joint gapping and improved mobility; and reciprocal inhibition (RI), where contraction of the antagonist muscle inhibits the agonist, allowing passive elongation without discomfort. These mechanisms make MET especially appropriate in the acute and subacute phases of cervical spondylosis when pain limits passive mobilization. Mulligan mobilization, through its unique combination of accessory

glide and active movement, addresses the positional fault hypothesis - the concept that minor malposition of facet joint surfaces contributes to pain and movement restriction. By correcting this positional fault through a pain-free accessory glide and guiding the patient through full range of active movement simultaneously, SNAGs restore normal arthrokinematics while simultaneously engaging central analgesic pathways. The moderate but significant NDI improvements in both groups (12.8 and 14.1 points respectively) indicate meaningful functional gains, with NDI reductions exceeding the MCID of 7.5 points. The complementary profiles of MET and Mulligan mobilization suggest they are best employed as part of a multimodal protocol rather than as standalone treatments.

**Clinical Implications**

The results suggest that a multimodal approach combining PNF Stretching for immediate pain relief and flexibility gains with Deep Cervical Flexion Strengthening for long-term muscle function may provide optimal outcomes. Clinicians should consider individual patient presentations, symptom severity, and treatment goals when selecting interventions. In the acute phase, MET and Mulligan mobilization offer pain-free entry points that improve joint mobility and prepare the cervical spine for more demanding interventions. As pain subsides and compliance improves, PNF stretching can be introduced to restore full ROM and neuromuscular coordination, before progressing to deep cervical flexor strengthening as the cornerstone of long-term structural rehabilitation. Patient education forms an essential adjunct to all interventions - addressing postural correction, ergonomic modification of workstations, and home exercise adherence significantly augments clinically delivered treatment effects [13]. Furthermore, clinicians should utilize the Neck Disability Index (NDI) as a routine monitoring tool to track functional progress and adjust treatment intensity accordingly. A patient-centered, goal-directed approach that integrates physical, psychological, and ergonomic dimensions of care is most likely to yield durable outcomes in the management of cervical spondylosis. The findings of this study support the development of structured, phased physiotherapy protocols that systematically progress through these four techniques in alignment with the patient's stage of recovery.

**Comparison with Previous Literature**

These findings are consistent with systematic reviews by Gross, et al. (2007) [2] and Vernon & Humphreys (2008) [3], which support the use of manual therapy and exercise for cervical disorders. The superior pain reduction with PNF aligns with Lewis, et al. (2009) [6], while the strength gains with deep cervical flexor exercises confirm findings by Falla, et al. (2004) [10] and Jull, et al. (1999) [11].

**Limitations**

This study has several limitations. The relatively small sample size (n=100) may limit the generalizability of findings to broader populations. The 4-week intervention period, while demonstrating significant improvements, may not capture long-term treatment effects. Additionally, the study was conducted at a single center, which may introduce selection bias. Future multi-center trials with larger sample sizes and extended follow-up periods are recommended to address these limitations. The absence of a true control group - either receiving no treatment or sham physiotherapy - prevents us from fully isolating the treatment-specific effects from non-specific therapeutic factors such as therapist attention, patient expectation, and the natural history of recovery. The blinding of outcome assessors was not confirmed, and given the nature of physiotherapy interventions, blinding of participants and therapists is inherently challenging, introducing a risk of performance and detection bias. The outcome measures used, while validated and widely accepted, predominantly capture self-reported and clinician-assessed functional outcomes; future studies would benefit from incorporating objective biomechanical measures such as ultrasound imaging of the longus colli, three-

dimensional motion analysis, and electromyographic assessment of deep cervical flexor activation to more precisely characterize neuromuscular adaptations. Patient adherence to the prescribed intervention frequency was not independently monitored, and differential adherence rates across groups could have introduced confounding. The exclusion of participants with myelopathy and radiculopathy, while ethically appropriate, limits the applicability of findings to these clinically important subgroups. Finally, potential moderating variables such as pain catastrophizing, kinesiophobia, and psychological comorbidities were not assessed; future research should explore these psychosocial predictors of treatment response to enable more personalized physiotherapy prescription [2, 3, 13].

## Conclusion

PNF Stretching is highly effective in reducing pain and improving ROM, while Deep Cervical Flexion Strengthening is most beneficial for muscle strength. Incorporating multimodal physiotherapy approaches can provide comprehensive benefits for cervical spondylosis. All four interventions demonstrated significant improvements, suggesting that individualized treatment selection based on patient presentation and goals is essential for optimal outcomes. This study contributes to the growing evidence base supporting the primacy of conservative, non-pharmacological management for cervical spondylosis. The comparative framework employed allows clinicians to make more informed decisions about technique selection based on the patient's dominant symptom profile - prioritizing PNF stretching and Mulligan mobilization in cases where pain and ROM restriction are the primary concerns, and emphasizing deep cervical flexor strengthening when postural instability, muscle weakness, and long-term structural rehabilitation are the primary goals. MET serves as an accessible and versatile first-line intervention across all clinical presentations. The effect sizes (Cohen's d range: 1.18–1.42) reported across all groups indicate large treatment effects that surpass most pharmacological comparators for neck pain, reinforcing the clinical value of physiotherapy as the preferred first-line treatment for cervical spondylosis. Future research should focus on developing and validating structured multimodal protocols, identifying clinical predictors of differential response to individual techniques, and evaluating long-term outcomes including recurrence rates, quality of life, and health economic impact. The integration of telerehabilitation platforms to support home-based deep cervical flexor training programs represents a promising avenue for extending the reach and durability of physiotherapy benefits in underserved populations. Ultimately, the evidence supports a personalized, evidence-based, and progressively phased physiotherapy approach as the cornerstone of cervical spondylosis management [2, 3, 4, 6, 10, 11, 12].

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