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Progress in Non-Surgical Physical Therapy for Cervical Spondylosis: Synergistic Application of Muscle Relaxation and Mechanical Correction

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ABSTRACT

Cervical spondylosis is a common degenerative disorder associated with neck pain, restricted mobility, sensorimotor dysfunction, and reduced quality of life. Although conservative treatment remains the first-line option for most patients, many physical therapy approaches continue to target isolated symptoms rather than the interacting muscular and biomechanical abnormalities that underlie disease progression. This review summarizes recent advances in non-surgical physical therapy for cervical spondylosis, with particular emphasis on the synergistic application of muscle relaxation and mechanical correction. Current evidence indicates that multimodal rehabilitation strategies are generally more effective than single-modality treatment. Cervical traction, exercise-based rehabilitation, manual therapy, and adjunctive physical modalities each contribute to symptom relief and functional improvement, but their clinical value appears greater when integrated within a coordinated rehabilitation framework. Muscle relaxation strategies may reduce hypertonicity, improve tissue extensibility, and enhance neuromuscular control, whereas mechanical correction may help restore cervical alignment, reduce abnormal loading, and relieve neural irritation. Their combination therefore offers a more comprehensive approach to both pain reduction and functional recovery. In addition, emerging intelligent rehabilitation technologies, including sensor-based traction systems, robotic devices, wearable assistive tools, computer vision, and artificial intelligence–assisted evaluation platforms, are expanding the possibilities for more standardized, measurable, and individualized rehabilitation. Overall, the integration of muscle relaxation with mechanical correction represents a promising direction in the conservative management of cervical spondylosis, while technology-enhanced rehabilitation may further support the transition from generalized intervention toward more precise and patient-specific care.

KEYWORDS

Cervical spondylosis; Conservative management; Physical therapy; Mechanical correction; Intelligent rehabilitation

1 Introduction

Cervical spondylosis is a common degenerative disorder of the cervical spine and a frequent cause of neck pain, restricted motion, and reduced daily function. Its clinical burden has increased not only with population aging but also with modern lifestyle changes, including prolonged screen exposure, forward-head posture, low physical activity, and repetitive cervical loading. As a result, cervical degenerative complaints are now increasingly observed across a broader age range rather than being limited to older adults.

Clinical manifestations are heterogeneous. Some patients mainly present with axial neck pain and stiffness, whereas others develop headache, limited range of motion, or upper-limb symptoms related to nerve root irritation. In more advanced cases, degenerative changes may contribute to foraminal narrowing, spinal canal compromise, or altered cervical curvature, thereby worsening pain and disability. This heterogeneity partly explains why treatment response is variable and why single therapeutic models are often insufficient.

Management is usually conservative. Surgery is generally reserved for marked neurological deficit, progressive myelopathy, or structural instability, whereas most mild-to-moderate cases are first treated with non-surgical measures such as medication, traction, exercise, manual therapy, and adjunctive physical modalities. Recent evidence continues to support the role of rehabilitation in degenerative cervical disorders. Ling et al. reported that structured postoperative rehabilitation improved recovery and functional outcomes in degenerative cervical spine disease [1].

Among conservative options, physical therapy remains one of the most adaptable approaches. Traction, stretching, strengthening, and motor-control training are commonly used to reduce pain and improve function. A randomized clinical trial found that traction combined with muscle relaxation improved pain, range of motion, and functional status in cervical radiculopathy [2], while ongoing trials are further evaluating standardized traction protocols [3]. These findings reflect a broader shift toward more evidence-based conservative rehabilitation.

However, many traditional non-surgical approaches still focus on isolated targets such as decompression, analgesia, or mobility. Cervical spondylosis, by contrast, usually involves interacting processes including muscle dysfunction, postural

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maladaptation, and biomechanical misalignment. Therefore, treatment directed at only one dimension may be beneficial but incomplete.

Against this background, combining muscle relaxation with mechanical correction becomes especially relevant. Muscle relaxation may reduce excessive tone and protective spasm, whereas mechanical correction strategies such as traction or mobilization may help restore alignment, reduce abnormal stress, and relieve neural irritation. This review therefore summarizes recent progress in non-surgical physical therapy for cervical spondylosis, with particular focus on the synergistic value of integrating muscle relaxation and biomechanical correction.

2 Pathophysiology of Cervical Spondylosis

Cervical spondylosis is a progressive degenerative process involving multiple components of the cervical motion segment, including intervertebral discs, vertebral bodies, facet joints, spinal ligaments, and surrounding musculature. Its clinical importance lies not simply in structural degeneration, but in the resulting disturbance of cervical biomechanics and, in some patients, neural compression. Accordingly, the disease spectrum ranges from chronic neck pain and radiculopathy to cervical myelopathy [4].

2.1 Intervertebral Disc Degeneration and Structural Alterations

Intervertebral disc degeneration is one of the earliest and most influential pathological events in cervical spondylosis. With aging and repetitive mechanical loading, the nucleus pulposus loses water and proteoglycan content, reducing disc elasticity and load-distribution capacity. As disc height declines, stress is redistributed to adjacent structures, accelerating segmental degeneration.

Disc degeneration is also accompanied by an inflammatory microenvironment. Pro-inflammatory mediators such as interleukin-1, interleukin-6, and tumor necrosis factor- α contribute to extracellular matrix breakdown and cellular apoptosis, indicating that degeneration is not merely passive wear but an active self-reinforcing process [5].

Secondary remodeling then develops, including osteophyte formation and facet joint degeneration. These changes can progressively narrow the neural foramina and spinal canal, increasing the likelihood of nerve root irritation or spinal cord compromise [6].

2.2 Ligament Degeneration and Spinal Canal Stenosis

Ligamentous degeneration is another important component of cervical spondylosis. Recurrent mechanical stress and chronic instability may lead to thickening or hypertrophy of the posterior longitudinal ligament and ligamentum flavum, thereby reducing canal space and aggravating neural compression .

In some patients, this process progresses to ossification of the posterior longitudinal ligament, shifting the clinical picture from pain or radiculopathy toward stenotic and myelopathic manifestations. When combined with osteophyte formation, ligament hypertrophy becomes a major contributor to spinal canal narrowing. Thus, cervical stenosis usually reflects the cumulative effect of several degenerative changes rather than one isolated lesion.

2.3 Cervical Muscle Dysfunction and Biomechanical Imbalance

Increasing attention has also been directed to cervical muscle dysfunction. Degeneration and fatty infiltration of the paraspinal muscles may reduce dynamic stability and alter force distribution across the cervical spine, thereby increasing stress on discs and facet joints and promoting further degeneration.

Postural factors further aggravate this process. Prolonged forward-head posture, sustained static positioning, and repetitive cervical loading disturb the balance between deep cervical flexors and posterior extensors, promoting abnormal curvature, inefficient load transfer, and tissue overuse. This may explain why some patients continue to experience chronic pain and stiffness even in the absence of prominent neural compression.

Taken together, cervical spondylosis is best understood as a multifactorial degenerative cascade involving disc degeneration, osteophyte formation, ligament hypertrophy, and muscular dysfunction. These processes interact to disrupt cervical biomechanics, sustain chronic pain, and increase the risk of neural compromise. This broader understanding supports rehabilitation strategies that address both muscular and biomechanical abnormalities rather than symptoms alone.

3 Current Non-Surgical Physical Therapies

Non-surgical physical therapy remains the main treatment for most patients with cervical spondylosis, particularly those with mild to moderate symptoms who do not require surgery. The goals are to relieve pain, improve mobility, reduce neural irritation when present, and restore daily function. Recent rehabilitation practice has increasingly shifted

from single-modality treatment toward combined strategies addressing the mechanical, muscular, and functional aspects of the disorder, which is more consistent with its multifactorial nature.

3.1 Cervical Traction and Spinal Decompression

Cervical traction remains one of the most commonly used conservative interventions, especially in patients with cervical radiculopathy related to degenerative change. By applying longitudinal distraction, traction may enlarge intervertebral space, reduce pressure on nerve roots, and decrease intradiscal stress, thereby improving symptoms and tolerance for further rehabilitation.

Recent studies support its symptomatic value, although optimal parameters and long-term effectiveness remain uncertain. A randomized controlled trial showed that intermittent mechanical traction improved postural balance and pain outcomes compared with sham traction in patients with cervical radiculopathy [7]. Another preliminary randomized study found that adding cervical traction to conventional rehabilitation improved cervicogenic headache, pain severity, and quality of life compared with lower-traction protocols [8]. Ongoing trials continue to evaluate standardized traction strategies .

Despite these benefits, traction is often more effective for short-term relief than as a stand-alone long-term solution. Its practical value may therefore lie in creating a more favorable mechanical condition for exercise, motor retraining, and other rehabilitation measures.

3.2 Exercise-Based Rehabilitation

Exercise-based rehabilitation is a cornerstone of conservative treatment for cervical spondylosis and chronic neck pain. Unlike passive modalities, it addresses weakness, impaired motor control, reduced endurance, postural maladaptation, and fear of movement. Common programs include strengthening, motor-control training, and self-mobilization to improve muscle performance and normalize movement patterns.

Recent studies have shown meaningful benefits from structured exercise. Cervical exercise combined with cervicothoracic self-mobilization improved pain, range of motion, and functional outcomes in chronic non-specific neck pain [9]. Systematic reviews and meta-analyses also support the overall role of exercise in reducing pain and disability, while indicating that effectiveness varies across exercise types and patient groups [10].

This variability is clinically important. Exercise therapy is often treated as a broad category, although interventions differ substantially in intensity, progression, and therapeutic target. Accordingly, clinical benefit depends less on exercise in general than on whether the program is matched to the patient ' s deficits in strength, posture, and motor control.

3.3 Adjunctive Modalities

Adjunctive physical modalities such as transcutaneous electrical nerve stimulation (TENS), thermal therapy, and neuromodulation-related techniques are commonly used to support rehabilitation. Their role is mainly supportive: although they do not directly correct underlying biomechanical abnormalities, they may reduce pain, relieve guarding, and improve participation in active treatment.

Recent studies suggest that these modalities can be useful when combined with other interventions. A randomized clinical trial found that myofascial release combined with TENS significantly improved pain intensity and neck disability in patients with neck myofascial syndrome [11]. Similarly, combining electrical stimulation with exercise improved pain and quality of life in patients with cervical radiculopathy [12].

Although their direct structural effects are limited, adjunctive modalities should not be viewed as merely incidental. Short-term analgesia and improved treatment tolerance may meaningfully influence rehabilitation adherence. For this reason, multimodal strategies integrating physical modalities with exercise and traction are increasingly favored over single-technique treatment.

Overall, current evidence supports a multimodal conservative approach to cervical spondylosis. Traction, exercise-based rehabilitation, and adjunctive modalities each serve different purposes, and their value is greater when they are integrated rather than used in isolation.

4 Synergistic Mechanism of Muscle Relaxation and Mechanical Correction

Non-surgical rehabilitation for cervical spondylosis has traditionally targeted pain relief, mobility, or decompression separately. Increasing evidence, however, suggests that combining muscular regulation with biomechanical correction may be more effective, because these strategies act on related but distinct components of cervical dysfunction.

4.1 Muscle Relaxation and Neuro-Musculoskeletal Adaptations

Muscle dysfunction contributes to persistent pain, limited motion, and impaired neuromuscular control in cervical spondylosis. Interventions that reduce stiffness, normalize tone, and improve elasticity may therefore lessen abnormal

loading and support functional recovery. A recent pilot study showed that structured rehabilitation reduced muscle stiffness and frequency in the cervical and shoulder girdle muscles, indicating improved muscle relaxation and contractile properties in patients with cervical spondylosis [13].

Manual techniques such as muscle energy techniques (MET) may also promote proprioceptive recovery. A randomized clinical trial comparing MET with cervical mobilization found that both reduced pain and disability, whereas MET further improved cervical position sense [14]. This suggests that muscle relaxation strategies may influence not only tone reduction but also sensory-motor control relevant to posture and movement stability.

4.2 Mechanical Correction and Spinal Alignment

Mechanical correction aims to restore more normal cervical biomechanics through traction, mobilization, or manipulation. These methods may reduce neural impingement, improve alignment, and help correct cervical curvature. In patients with mechanical neck pain, adding cervical manipulation to exercise therapy produced faster improvement in pain, range of motion, and sagittal alignment than exercise alone [15]. Although not limited to established cervical spondylosis, this finding still supports the rehabilitation value of biomechanical correction.

Finite element studies further indicate that muscle imbalance alters load distribution across cervical segments and increases stress on discs and facet joints [16]. This implies that mechanical correction alone may be insufficient if abnormal muscular forces remain unaddressed.

4.3 Integrated Therapeutic Model

Current evidence therefore supports an integrated model combining muscle relaxation with mechanical correction. Muscle relaxation may reduce hypertonicity, improve tissue extensibility, and enhance proprioceptive input, thereby preparing the cervical region for mechanical intervention. Mechanical correction may then restore alignment, reduce compressive stress, and improve joint function. Used together, these approaches may provide more effective pain relief, mobility improvement, and functional stability than either strategy alone.

5 Emerging Intelligent Rehabilitation Devices

Recent advances in rehabilitation engineering have expanded cervical rehabilitation beyond traditional physical modalities. Intelligent devices integrate sensors, actuators, and control systems to deliver more standardized and potentially individualized treatment. In cervical spondylosis, these technologies are being explored to improve treatment precision, reproducibility, and patient engagement.

5.1 Intelligent Traction and Alignment Systems

Cervical traction is gradually evolving from simple mechanical devices toward computer-assisted and sensor-based systems that can monitor and adjust treatment parameters. Emerging designs allow computerized control of traction angle and force, which may support more individualized correction of cervical curvature and posture [17].

Direct clinical evidence for smart cervical traction remains limited. However, developments in other rehabilitation fields suggest that automation and feedback control may improve the consistency and repeatability of conventional therapies, providing a reasonable technical basis for future cervical applications.

5.2 Robotic and Mechatronic Neck Rehabilitation Systems

Robotic and mechatronic systems are also being investigated for cervical rehabilitation. These devices can provide precise movement guidance, adjustable loading, and interactive exercise modes that are difficult to reproduce manually. One study described a six-degrees-of-freedom cable-driven robotic platform for controlled head-neck movement and quantitative muscle response assessment, highlighting the potential of robotic platforms for individualized rehabilitation [18].

Dedicated neck rehabilitation robots have also been developed to provide controlled resistance training with posture feedback. By incorporating force sensors, gyroscopes, and monitoring components, these systems may reduce compensatory movement and improve safety during training [19]. Their main advantage is the ability to deliver more consistent and measurable training stimuli than manual therapy alone.

5.3 Wearable Assistive Devices and Sensor-Based Feedback

Wearable rehabilitation devices are another promising direction, particularly for home-based or long-term therapy. Systems designed to assist head and neck movement may support functional training outside hospital settings while monitoring movement quality. A recent study demonstrated the feasibility of a wearable device providing three-dimensional motion assistance for head-neck rehabilitation [20].

Reviews of wearable assistive robotics have likewise emphasized the importance of combining actuators, sensors, and control strategies to improve responsiveness and range of motion in head and neck rehabilitation systems [21]. Although

not yet widely translated into routine cervical spondylosis care, these devices reflect a clear shift toward more adaptive and patient-centered rehabilitation technologies.

5.4 AI-Assisted Evaluation and Digital Rehabilitation

Another emerging area is artificial intelligence–assisted rehabilitation assessment and treatment support. AI-assisted systems have shown value in musculoskeletal rehabilitation by improving pain, range of motion, and functional recovery across different settings . For cervical disorders, this suggests that digital platforms may eventually help clinicians select, monitor, and refine rehabilitation strategies more precisely.

Computer vision–based methods have also been introduced for cervical rehabilitation evaluation. One study proposed an intelligent visual assessment method indicating that posture and movement performance can be quantified more objectively through digital tools . Although these methods remain at an early stage, they point toward a more data-driven and individualized model of cervical rehabilitation.

6 Future Perspectives

Non-surgical management of cervical spondylosis is moving toward more precise and technology-supported rehabilitation. Advances in digital health, artificial intelligence, and personalized treatment design are beginning to reshape rehabilitation by making it more measurable, adaptive, and individualized.

One important direction is AI-assisted rehabilitation and digital therapeutics. AI-driven systems, including robotic rehabilitation, exergaming platforms, and motion-analysis tools, have shown potential to improve pain, range of motion, and functional outcomes in musculoskeletal disorders [22]. By processing movement and symptom data in real time, these systems may help optimize treatment progression and improve patient participation.

Another promising area is computer vision and sensor-based evaluation. Intelligent assessment systems can track cervical motion, guide exercise performance, and provide automated feedback with less dependence on continuous therapist supervision, which may be especially useful in home-based and long-term rehabilitation [23].

Virtual and augmented reality are also being explored as supportive rehabilitation tools. Immersive digital environments may enhance engagement, facilitate neuromuscular retraining, and provide task-oriented sensory feedback. Early clinical exploration in postoperative cervical rehabilitation suggests potential value in motor recovery and symptom control [24].

AI is also influencing diagnosis, prediction, and decision support in spine care. AI-based imaging analysis may improve the evaluation of cervical alignment, disc degeneration, and neural compression, while predictive models may support treatment planning and prognosis assessment. Still, long-term validation, protocol standardization, and broader accessibility are needed before these technologies can be fully integrated into routine care.

7 Conclusion

Non-surgical physical therapy remains central to cervical spondylosis management and can improve pain, function, and quality of life. Current evidence supports multimodal conservative treatment, particularly approaches combining traction, exercise-based rehabilitation, and adjunctive physical modalities to address the complex pathophysiology of the disease . However, variable treatment response and limited long-term adherence still constrain the effectiveness of traditional approaches alone.

An integrated model combining muscle relaxation with mechanical correction offers a more complete rehabilitation strategy by addressing both neuromuscular dysfunction and biomechanical imbalance. At the same time, emerging technologies such as intelligent traction systems, rehabilitation robots, wearable devices, and AI-assisted tools may further improve the precision and personalization of conservative treatment [25]. Overall, individualized and technology-enhanced rehabilitation appears to be a promising direction for improving cervical spondylosis care.

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