

Cervical Sagittal Imbalance in Degenerative Cervical Disease: Biomechanics, Imaging Assessment, and Stepwise Rehabilitation

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Abstract: Degenerative cervical disease is commonly evaluated for disc degeneration, stenosis, and neural compression. Sagittal alignment, however, is also relevant to cervical function. A reduction in cervical lordosis or forward translation of the head changes how loads are distributed across the neck. Deep cervical muscles contribute to segmental control, and their recruitment and morphology may change with altered alignment. Current evidence, however, does not establish a causal relationship. Assessment may therefore combine the C2-C7 Cobb angle, cervical sagittal vertical axis (cSVA), and T1 slope (T1S) with dynamic imaging and MRI evaluation of cervical muscles. This review examines sagittal imbalance, cervical muscle dysfunction, and their implications for rehabilitation. Particular attention is given to deep-muscle training and multi-angle resistance exercise, whose clinical value requires further evaluation.

Keywords: cervical degeneration; sagittal balance; deep cervical muscles; biomechanics; imaging; rehabilitation

1. Introduction

Degenerative cervical disease affects the discs, vertebral bodies, facet joints, ligaments, and surrounding soft tissues. Beyond stenosis and neural compression, sagittal alignment is relevant to cervical function [1]. Disc-height loss and joint degeneration may alter cervical curvature, while pain and impaired motor control can affect muscle recruitment. Alignment and muscular control thus interact in determining cervical loading.

Static radiographs can identify loss of lordosis but provide limited information about cervical control during movement or loading. Rehabilitation assessment should therefore consider muscular performance together with structural alignment.

2. Biomechanical Basis of Cervical Sagittal Imbalance

The cervical spine supports the head while allowing substantial mobility. Sagittal balance is assessed using the C2-C7 Cobb angle, cervical sagittal vertical axis (cSVA), and T1 slope (T1S), with T1S related to cervical lordosis [1]. Reduced lordosis or anterior head translation lengthens the moment arm of head weight, increasing demand on the posterior cervical muscles and potentially increasing disc and facet loading.

Cervical alignment varies with flexion and extension, so a neutral image may not reflect motion-related changes. In degenerative cervical disease, kinematic MRI has linked T1S and C2-C7 alignment with cervical motion [2].

The longus colli and longus capitis contribute to anterior segmental control, while the multifidus and semispinalis cervicis support posterior stability. Chronic neck pain has been associated with reduced deep-flexor recruitment and greater superficial muscle activity, a pattern that may respond to targeted exercise [3]. MRI has also identified altered deep-to-superficial and flexor-to-extensor muscle relationships in cervical spondylotic myelopathy, particularly with degenerative kyphosis [4]. These findings suggest an association between muscle imbalance and sagittal malalignment, but do not establish causality.

3. Imaging and Functional Assessment

Standing lateral radiographs remain the basic tool for assessing cervical sagittal alignment. The C2-C7 Cobb angle describes lordosis, cSVA reflects anterior head translation, and T1S represents the orientation of the cervicothoracic junction. Because each captures a different aspect of alignment, they are best interpreted together [1].

Static images provide limited information about motion. Flexion-extension radiographs can reveal segmental mobility and deformity flexibility, while kinematic MRI evaluates cervical movement together with neural structures [2]. These methods may help when neutral imaging does not adequately explain functional limitations.

MRI can also show muscle cross-sectional area, fatty infiltration, and deep-to-superficial muscle relationships [4]. Such findings describe morphology rather than function. Strength, endurance, and craniocervical flexion testing are therefore

useful complementary assessments.

4. Rehabilitation and Multi-Angle Resistance Training

Conservative rehabilitation is appropriate in the absence of progressive neurological deficits. Early management may reduce sustained neck loading while maintaining cervical movement. Deep cervical flexor training can improve motor control [3], although reported effects on strength, endurance, and muscle morphology vary [5,6]. Pressure biofeedback may further improve deep-flexor endurance [7].

As control improves, resistance and endurance exercise can be progressed according to individual tolerance. Deep cervical exercises have been associated with improvements in pain, disability, posture, and strength [8], with additional evidence supporting gains in deep-flexor performance [9]. Training should therefore be adjusted to individual capacity rather than follow a fixed loading scheme.

Multi-angle training can assess flexion, extension, lateral flexion, and rotation separately. An instrumented system may quantify force, endurance, asymmetry, and angle-specific deficits, allowing resistance to be adjusted to individual capacity. This supports adaptive cervical training, but its superiority over established exercise remains unproven.

Progressive myelopathy, marked neural compression, or fixed deformity requires specialist assessment, and surgery may be indicated [10]. Postoperative rehabilitation can then gradually restore cervical control, endurance, and strength.

5. Clinical Implications and Conclusion

Cervical sagittal imbalance reflects both structural degeneration and muscular control. Static alignment alone may therefore not fully explain symptoms or functional limitations.

Assessment can combine sagittal parameters with dynamic imaging and muscle-performance testing. Rehabilitation should progress from motor control to resistance and endurance training according to individual capacity. Multi-angle adaptive resistance may help quantify deficits and guide training, but its clinical advantage remains unproven. Further controlled studies should determine whether improved muscle performance translates into better function or sagittal alignment.

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References

- [1] Azimi P, Yazdanian T, Benzel EC, et al. Sagittal balance of the cervical spine: a systematic review and meta-analysis. *Eur Spine J*. 2021;30(6):1411–1439. doi:10.1007/s00586-021-06825-0.
- [2] Weng C, Wang J, Tuchman A, et al. Influence of T1 slope on the cervical sagittal balance in degenerative cervical spine: an analysis using kinematic MRI. *Spine (Phila Pa 1976)*. 2016;41(3):185–190. doi:10.1097/BRS.0000000000001353.
- [3] Jull GA, Falla D, Vicenzino B, Hodges PW. The effect of therapeutic exercise on activation of the deep cervical flexor muscles in people with chronic neck pain. *Man Ther*. 2009;14(6):696–701. doi:10.1016/j.math.2009.05.004.
- [4] Wang H, Xu H, Wang X, et al. Imbalance of muscles around the cervical spine in patients with degenerative cervical spondylotic kyphosis and myelopathy. *World Neurosurg*. 2025;195:123605. doi:10.1016/j.wneu.2024.123605.
- [5] Blomgren J, Strandell E, Jull G, et al. Effects of deep cervical flexor training on impaired physiological functions associated with chronic neck pain: a systematic review. *BMC Musculoskelet Disord*. 2018;19:415. doi:10.1186/s12891-018-2324-z.
- [6] Amiri Arimi S, Mohseni Bandpei MA, Javanshir K, et al. The effect of different exercise programs on size and function of deep cervical flexor muscles in patients with chronic nonspecific neck pain: a systematic review of randomized controlled trials. *Am J Phys Med Rehabil*. 2017;96(8):582–588. doi:10.1097/PHM.0000000000000721.
- [7] Ashfaq R, Riaz H. Effect of pressure biofeedback training on deep cervical flexors endurance in patients with mechanical neck pain: a randomized controlled trial. *Pak J Med Sci*. 2021;37(2):550–555. doi:10.12669/pjms.37.2.2343.
- [8] Suvarnnato T, Puntumetakul R, Uthairakul S, Boucaut R. Effect of specific deep cervical muscle exercises on functional disability, pain intensity, craniovertebral angle, and neck-muscle strength in chronic mechanical neck pain: a randomized controlled trial. *J Pain Res*. 2019;12:915–925. doi:10.2147/JPR.S190125.
- [9] Chaiyawijit S, Kanlayanaphotporn R. McKenzie neck exercise versus cranio-cervical flexion exercise on strength and endurance of deep neck flexor muscles, pain, disability, and craniovertebral angle in individuals with chronic neck pain: a randomized clinical trial. *J Man Manip Ther*. 2024;32(6):573–583. doi:10.1080/10669817.2024.2337979.

- [10] Gallagher DO, Taghlabi KM, Bondar K, Saifi C. Degenerative cervical myelopathy: a concept review and clinical approach. *Clin Spine Surg.* 2024;37(1):1–8. doi:10.1097/BSD.0000000000001463.