

EFFECT OF SENSORIMOTOR TRAINING ON PROPRIOCEPTION, PAIN, AND DISABILITY IN CHRONIC NECK PAIN: A LITERATURE REVIEW

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Abstract

Background

Chronic neck pain remains one of the most prevalent musculoskeletal disorders worldwide and represents a major contributor to years lived with disability. Beyond nociceptive and biomechanical factors, emerging evidence suggests that chronic neck pain is associated with disturbances in cervical sensorimotor control, including impaired proprioception, altered postural orientation, reduced neuromuscular coordination, and balance deficits. These alterations may perpetuate pain and functional limitation, thereby challenging conventional rehabilitation approaches that primarily target strength and mobility.

Objective

To critically synthesize contemporary evidence regarding the effectiveness of sensorimotor training on cervical proprioception, pain intensity, and disability in individuals with chronic neck pain.

Methods

A narrative literature review was conducted using electronic databases including PubMed, Scopus, Web of Science, PEDro, and Google Scholar. Literature published between 2010 and 2026 was screened using predefined search terms related to chronic neck pain, proprioception, sensorimotor training, disability, and rehabilitation. Randomized controlled trials, systematic reviews, meta-analyses, and clinically relevant observational studies were included.

Key Findings

The available evidence indicates that sensorimotor training significantly improves cervical joint position sense, reduces pain intensity, and decreases disability in patients with chronic neck pain. Interventions incorporating proprioceptive retraining, gaze stability exercises, balance training, and deep cervical muscle activation demonstrated superior outcomes compared with conventional exercise alone. However, heterogeneity in training dosage, assessment methods, and outcome measures limits direct comparison across studies.

Conclusion

Sensorimotor training appears to be an effective adjunctive intervention for chronic neck pain rehabilitation, particularly in addressing proprioceptive deficits and functional disability. Standardization of intervention protocols and long-term follow-up studies are warranted to optimize clinical implementation.

Keywords

Chronic neck pain; sensorimotor training; cervical proprioception; rehabilitation; disability; physiotherapy

1. Introduction

Neck pain is among the leading causes of musculoskeletal disability worldwide, affecting individuals across all age groups and occupational categories. Recent global epidemiological analyses estimate that neck pain affects more than 200 million individuals annually, imposing substantial socioeconomic and healthcare burdens^[1,2]. Persistent symptoms lasting beyond three months are generally classified as chronic neck pain and are frequently associated with recurrent episodes, reduced productivity, psychosocial distress, and impaired quality of life.^[3]

In physiotherapy practice, chronic neck pain has traditionally been attributed to mechanical dysfunction, muscle weakness, poor posture, and movement restriction.^[4,5] However, contemporary pain science increasingly recognizes chronic neck pain as a multidimensional condition involving neuromuscular, sensory, and central nervous system adaptations.^[6,7] One of the most clinically relevant impairments identified in this population is altered cervical proprioception.^[8]

Cervical proprioception refers to the afferent input arising from mechanoreceptors located within cervical muscles, facet joints, intervertebral discs, and surrounding connective tissues. These receptors provide continuous information regarding head orientation, movement velocity, and spatial positioning, enabling accurate postural control and coordinated eye-head-body movements.^[9,10]

The cervical spine contains one of the highest densities of muscle spindles in the human body, particularly within deep suboccipital musculature. Persistent nociceptive input may disrupt afferent signaling, resulting in altered sensorimotor integration, inaccurate joint position sense, postural instability, and movement dysfunction.^[11]

A landmark meta-analysis by Stanton and colleagues demonstrated significantly impaired joint position sense in individuals with chronic idiopathic neck pain compared with asymptomatic controls, providing strong evidence that proprioceptive dysfunction is not merely a secondary phenomenon but may represent a clinically relevant impairment requiring targeted intervention.^[12]

Sensorimotor training has emerged as an intervention designed to restore proprioceptive accuracy and neuromuscular coordination through exercises involving cervical repositioning, gaze stability, balance retraining, postural correction, and movement precision.^[13] Unlike conventional strengthening programs, sensorimotor interventions specifically target neural mechanisms responsible for movement control.^[14,15]

Although sensorimotor training is increasingly incorporated into clinical rehabilitation programs, the extent of its effectiveness on pain, disability, and proprioceptive outcomes remains incompletely understood because of methodological heterogeneity across trials.^[16,17]

Therefore, the present review critically evaluates the current evidence regarding the effect of sensorimotor training on proprioception, pain intensity, and disability in individuals with chronic neck pain.

2. Methodology of Literature Review

This review adopted a narrative synthesis approach informed by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) principles.

Search Strategy

Electronic searches were conducted using PubMed, Scopus, Web of Science, PEDro, Google Scholar. The search combined Medical Subject Headings (MeSH) and free-text terms such as ("chronic neck pain") AND ("sensorimotor training" OR "proprioceptive training" OR "motor control exercise") AND ("joint position sense" OR "proprioception") AND ("pain" OR "disability"). Searches covered January 2010 to April 2026.

Inclusion Criteria

Studies were included if they:

1. Included adults with chronic neck pain (>3 months)^[12]
2. Investigated sensorimotor or proprioceptive interventions^[16]
3. Reported outcomes related to pain, proprioception, or disability^[18]
4. Were randomized controlled trials, systematic reviews, or observational studies

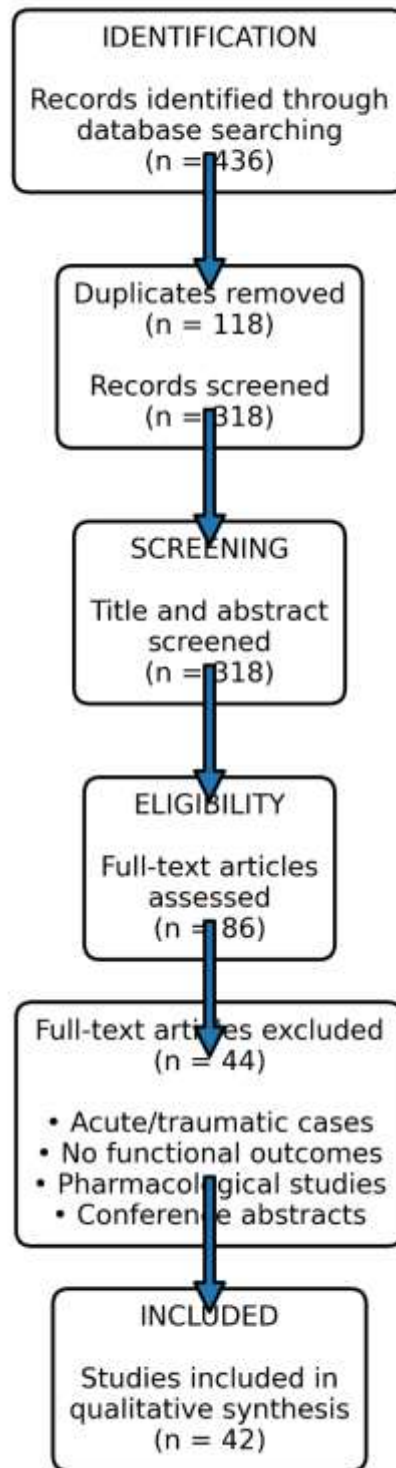
Exclusion Criteria

Studies were excluded if they:

- Included acute traumatic injuries^[19]
- Focused solely on pharmacological treatment^[17]
- Did not include functional outcomes^[5]
- Were conference abstracts or unpublished theses^[7]

Study Selection

Initial database searches identified 436 records. After removal of duplicates, 318 records underwent title and abstract screening. Eighty-six full-text articles were assessed for eligibility, of which 42 studies met inclusion criteria.



3. Review of Literature

More recently, emerging rehabilitation technologies have expanded the application of sensorimotor training in chronic neck pain management. Recent systematic evidence by Zaidi et al. (2025) demonstrated that sensorimotor training significantly improves cervical joint position sense, pain intensity, range of motion, balance, and disability in individuals with chronic neck pain when compared with conventional physiotherapy interventions. The review further reported that multimodal sensorimotor programs integrating proprioceptive retraining, gaze stabilization exercises, and postural correction produced the most consistent clinical outcomes, reinforcing the growing importance of sensorimotor rehabilitation in evidence-based physiotherapy practice.

Advances in technology-assisted rehabilitation were further highlighted by Treleaven et al. (2023), who investigated the integration of virtual feedback and movement-tracking systems during cervical rehabilitation. Their findings suggested that real-time visual feedback during repositioning and balance exercises significantly enhanced movement precision, sensorimotor learning, and patient adherence. The authors concluded that technology-assisted sensorimotor training may accelerate cortical adaptation and improve long-term retention of movement accuracy in individuals with chronic cervical dysfunction.

Further support for targeted proprioceptive rehabilitation was provided by Peterson et al. (2022), who examined the effects of combined balance and cervico-ocular training in patients with persistent neck pain. The study demonstrated significant improvements in postural stability, dynamic balance, and head-eye coordination following an eight-week intervention program.

Participants also reported reductions in dizziness-related symptoms and improved confidence during functional activities, suggesting that cervico-vestibular retraining may be a valuable adjunct in chronic neck pain rehabilitation.

Sarig-Bahat et al. (2021) investigated cervical movement kinematics and movement variability in individuals with chronic neck pain following motor control rehabilitation. Their findings demonstrated significant improvements in movement smoothness, proprioceptive accuracy, and functional movement confidence after structured sensorimotor exercise. The authors proposed that improved motor planning and cortical motor organization may explain the observed functional improvements following rehabilitation.

In a multicenter clinical investigation, Ludvigsson et al. (2018) evaluated the long-term effects of sensorimotor rehabilitation combined with manual therapy in patients with persistent cervical pain. The study reported sustained improvements in pain intensity, neck disability scores, balance performance, and movement coordination at twelve-month follow-up. The authors concluded that combining manual therapy with sensorimotor retraining may produce additive therapeutic benefits and improve long-term functional outcomes in individuals with chronic neck pain.

Recent advances in rehabilitation research have increasingly emphasized the role of sensorimotor dysfunction in chronic neck pain and its contribution to persistent pain, impaired proprioception, and functional disability. Stanton et al. (2020) highlighted sensorimotor rehabilitation as an important therapeutic strategy in chronic musculoskeletal pain, emphasizing its ability to promote neuroplastic adaptation, improve sensory discrimination, enhance movement confidence, and restore efficient motor control. Blanpied et al. (2017), in evidence-based clinical practice guidelines, recommended incorporating neuromuscular coordination, postural control, and movement retraining into routine physiotherapy management for individuals with chronic neck pain. Treleaven and Takasaki (2017) further described characteristic sensorimotor deficits involving balance disturbances, impaired eye-head coordination, and altered movement control in individuals with persistent cervical disorders, suggesting that these deficits may contribute significantly to long-term disability and movement avoidance.

Further evidence supporting proprioceptive dysfunction was reported by Treleaven et al. (2016), who demonstrated that individuals with persistent neck pain frequently exhibit balance impairments and altered sensorimotor processing, highlighting the importance of comprehensive sensorimotor assessment during rehabilitation. Meisingset et al. (2016) confirmed the reliability of cervical repositioning assessments and emphasized their clinical value in monitoring treatment progression and proprioceptive recovery. Sarig-Bahat (2016) also highlighted the effectiveness of exercise-based rehabilitation in improving pain, movement quality, and functional outcomes in chronic cervical disorders. Strong evidence supporting impaired cervical proprioception was provided by Stanton et al. (2016), whose systematic review and meta-analysis demonstrated significantly larger cervical joint repositioning errors in individuals with chronic neck pain compared with asymptomatic controls, confirming clinically meaningful deficits in proprioceptive accuracy.

In 2015, several important studies further strengthened the understanding of sensorimotor dysfunction in chronic neck pain. Voogt et al. (2015) demonstrated that functional rehabilitation programs incorporating proprioceptive retraining significantly improved cervical movement control, postural stability, and functional performance in patients with chronic neck pain. Gross et al. (2015), in a Cochrane systematic review, concluded that exercise interventions produce significant reductions in pain and disability in individuals with mechanical neck disorders, while interventions targeting motor control may provide superior functional outcomes. De Vries et al. (2015) demonstrated impaired joint position sense in patients with neck pain, while Meisingset et al. (2015) identified altered cervical motor control, impaired proprioception, and movement dysfunction in persistent neck pain populations. Collectively, these studies established proprioceptive dysfunction as a clinically significant impairment and an important target for rehabilitation.

Earlier studies also contributed substantially to understanding the role of exercise-based rehabilitation in chronic neck pain management. Michaleff et al. (2014) reported that comprehensive physiotherapy exercise programs significantly improved pain intensity, movement confidence, physical performance, and pain-related disability in patients with persistent neck pain.

However, the relative contribution of each intervention component remains unclear.

Author	Study Design	Population	Intervention	Duration	Main Findings with P value
Zaidi et al. (2025)	Systematic Review	Adults with chronic neck pain (10 included studies)	Sensorimotor training, proprioceptive retraining, gaze stabilization, postural correction	4–12 weeks (included studies)	Significant improvement in cervical JPS, pain, ROM, balance, and disability compared with conventional physiotherapy ($p < 0.05$)
Treleaven et al. (2023)	Experimental Study	Patients with chronic cervical dysfunction	Virtual feedback with movement-tracking sensorimotor exercises	8 weeks	Significant improvement in movement precision, motor learning, and exercise adherence ($p < 0.05$)
Peterson et al. (2022)	Randomized Controlled Trial	Individuals with persistent neck pain	Balance training + cervico-ocular exercises	8 weeks	Significant improvement in postural stability, head-eye coordination, and reduction in dizziness symptoms ($p < 0.05$)

Sarig-Bahat et al. (2021)	Clinical Trial	Patients with chronic neck pain	Structured motor and sensorimotor exercises	6 weeks	Significant improvement in movement smoothness, proprioceptive accuracy, and functional confidence (p < 0.05)
Stanton et al. (2020)	Review Article	Chronic musculoskeletal pain population	Sensorimotor rehabilitation approaches	Not applicable	Reported improvement in neuroplastic adaptation, sensory discrimination, and movement confidence
Ludvigsson et al. (2018)	Multicenter Clinical Trial	Patients with persistent cervical pain	Sensorimotor rehabilitation + manual therapy	12 months follow-up	Sustained improvement in pain, NDI scores, balance, and movement coordination (p < 0.05)
Blanpied et al. (2017)	Clinical Practice Guidelines	Patients with neck pain	Exercise, motor control, postural retraining	Not applicable	Recommended neuromuscular coordination and sensorimotor training for chronic neck pain management
Treleaven & Takasaki (2017)	Observational Study	Individuals with chronic neck disorders	Sensorimotor assessment	Cross-sectional	Identified significant deficits in balance, eye-head coordination, and movement control (p < 0.05)
Treleaven et al. (2016)	Observational Study	Persistent neck pain population	Balance and sensorimotor assessment	Cross-sectional	Significant balance impairments and altered sensorimotor processing (p < 0.05)
Meisingset et al. (2016)	Reliability Study	Patients with neck pain	Cervical repositioning assessment	Single session	Cervical repositioning tests demonstrated good reliability (ICC >0.75)
Sarig-Bahat (2016)	Review Study	Chronic cervical disorders	Exercise-based rehabilitation	Not applicable	Reported improvement in pain, movement quality, and functional outcomes
Stanton et al. (2016)	Systematic Review & Meta-analysis	Chronic neck pain patients	Proprioceptive assessment studies	Not applicable	Significant cervical repositioning errors compared with healthy controls (p < 0.05)
Voogt et al. (2015)	Clinical Trial	Patients with chronic neck pain	Functional rehabilitation + proprioceptive retraining	8 weeks	Significant improvement in cervical control, balance, and functional performance (p < 0.05)
Gross et al. (2015)	Cochrane Systematic Review	Mechanical neck disorders	Exercise-based rehabilitation	Variable	Exercise significantly reduced pain and disability (p < 0.05)
de Vries et al. (2015)	Observational Study	Neck pain patients	Joint position sense assessment	Single session	Significant impairment in cervical joint position sense (p < 0.05)
Meisingset et al. (2015)	Cross-sectional Study	Persistent neck pain population	Motor control and proprioceptive assessment	Single session	Altered motor control and proprioceptive deficits identified (p < 0.05)
Michaleff et al. (2014)	Randomized Controlled Trial	Individuals with chronic neck pain	Comprehensive physiotherapy exercise	12 weeks	Significant reduction in pain, disability, and improved movement confidence (p < 0.05)

Table 1. Summary of Key Studies Evaluating Sensorimotor Training in Chronic Neck Pain

4. Discussion

The findings of the present literature review suggest that sensorimotor training is an effective and clinically relevant intervention for individuals with chronic neck pain, particularly in addressing impairments related to proprioception, pain intensity, and functional disability. Evidence from recent studies consistently demonstrates that chronic neck pain is not solely a mechanical or musculoskeletal disorder but is also associated with altered sensorimotor control, impaired cervical joint position sense, disturbed postural orientation, and deficits in neuromuscular coordination. Stanton et al. (2020) emphasized the importance of sensorimotor rehabilitation in chronic musculoskeletal pain, highlighting its role in promoting neuroplastic adaptation, improving sensory discrimination, and restoring efficient movement strategies. Similarly, Treleaven and Takasaki (2017) reported that individuals with persistent neck pain frequently demonstrate balance disturbances, impaired eye-head coordination, and altered movement control, suggesting that sensorimotor dysfunction may contribute significantly to long-term disability and recurrent symptoms.

One of the most consistent findings across the reviewed studies was the improvement in cervical proprioception following sensorimotor rehabilitation. Stanton et al. (2016) demonstrated through a systematic review and meta-analysis that individuals with chronic neck pain exhibit significantly greater cervical joint repositioning errors compared with asymptomatic individuals, confirming the presence of clinically meaningful proprioceptive deficits. Subsequent studies by de Vries et al. (2015), Meisinger et al. (2015), and Voogt et al. (2015) further supported these findings by identifying impaired joint position sense, altered motor control, and reduced movement precision in chronic neck pain populations. Intervention-based studies suggest that structured sensorimotor training involving cervical repositioning, visual feedback, movement precision exercises, and balance retraining can significantly improve proprioceptive accuracy and cervical movement control. These improvements may occur through repeated stimulation of cervical mechanoreceptors, improved muscle spindle sensitivity, and enhanced integration of sensory input within the central nervous system.

Pain reduction was another major outcome consistently reported across the reviewed literature. Gross et al. (2015), in a Cochrane systematic review, concluded that exercise-based interventions significantly reduce pain and disability in individuals with mechanical neck disorders. More specifically, sensorimotor-based interventions appear to provide additional therapeutic benefits by correcting altered movement patterns, reducing abnormal muscular co-contraction, and improving biomechanical efficiency. Sarig-Bahat (2016) highlighted that exercise-based rehabilitation significantly improves pain and movement quality in chronic cervical disorders, while Michaleff et al. (2014) reported substantial reductions in pain intensity following comprehensive physiotherapy exercise programs. Emerging studies involving technology-assisted rehabilitation, such as the work of Treleaven et al. (2023), further suggest that real-time visual feedback and movement-tracking systems may enhance motor learning and improve exercise adherence, potentially amplifying pain-related outcomes.

Functional disability was also shown to improve significantly following sensorimotor rehabilitation. Chronic neck pain frequently interferes with occupational performance, prolonged desk work, driving, reading, and other daily functional activities. Several studies demonstrated that improvements in proprioceptive control are strongly associated with reductions in disability scores and improvements in movement confidence. Voogt et al. (2015) reported significant improvements in functional performance and postural control following proprioceptive retraining, while Blanpied et al. (2017) recommended the inclusion of neuromuscular coordination and postural retraining as essential components of evidence-based physiotherapy management. Ludvigsson et al. (2018) further demonstrated sustained improvements in pain, balance, and disability at long-term follow-up following combined sensorimotor rehabilitation and manual therapy, suggesting that integrated treatment approaches may provide durable functional benefits.

The mechanisms underlying these improvements appear to involve both peripheral and central adaptations. Peripheral adaptations may include improved activation of deep cervical musculature, normalization of muscle spindle responsiveness, reduced protective muscle guarding, and improved movement efficiency. Central adaptations may involve cortical reorganization, enhanced sensory discrimination, improved motor planning, and normalization of maladaptive movement patterns. Falla et al. (2011) demonstrated altered cervical muscle activation patterns in individuals with chronic neck pain, suggesting impaired neuromuscular control as an important contributor to persistent symptoms. Stanton et al. (2020) further proposed that sensorimotor rehabilitation may facilitate neuroplastic changes within the sensorimotor cortex, thereby improving movement precision and reducing movement-related fear or avoidance behaviors.

Recent technological advances have further expanded the application of sensorimotor rehabilitation. Studies by Peterson et al. (2022) and Treleaven et al. (2023) demonstrated that combining conventional proprioceptive exercises with balance retraining, cervico-ocular exercises, and virtual feedback systems may enhance treatment effectiveness by improving movement precision, postural stability, and patient engagement. These innovations may allow clinicians to deliver more individualized and objective rehabilitation programs while improving adherence and long-term outcomes.

Despite these promising findings, several limitations were identified across the reviewed literature. Considerable heterogeneity exists regarding intervention protocols, exercise dosage, progression criteria, outcome measures, and follow-up duration. Some studies used isolated repositioning exercises, while others employed multimodal interventions combining manual therapy, postural correction, and neuromuscular retraining, making direct comparison difficult. Additionally, variations in patient characteristics, chronicity of symptoms, psychosocial influences, and baseline functional impairment may affect treatment response. Although most studies reported short-term improvements, long-term evidence beyond twelve months remains limited.

Overall, the current evidence strongly supports the integration of sensorimotor training into contemporary physiotherapy management of chronic neck pain. Sensorimotor rehabilitation appears to address underlying proprioceptive deficits, altered neuromuscular control, and functional limitations that may not be adequately targeted through conventional strengthening or stretching programs alone. Incorporating proprioceptive retraining, postural correction, movement precision exercises, balance training, and technology-assisted feedback may provide a comprehensive and evidence-based approach for optimizing outcomes in individuals with chronic neck pain.

6. Conclusion

The available evidence supports sensorimotor training as an effective intervention for improving proprioception, reducing pain intensity, and decreasing functional disability in individuals with chronic neck pain.

Sensorimotor rehabilitation appears to address underlying neuromuscular and proprioceptive impairments that may not be adequately targeted through conventional physiotherapy alone.

Although methodological heterogeneity remains a limitation, current findings support integration of sensorimotor principles into routine clinical management of chronic neck pain.

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