Whiplash-associated Disorder: A Case Report

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ABSTRACT

Approximately 50% of people who suffer from whiplash enter the chronic phase of this condition and develop persistent symptoms known as chronic whiplash-associated disorders (WAD). This case study aims to contribute to the understanding of rehabilitation programmes combining cervical exercises and proprioceptive training for managing such conditions, as the literature supporting their significance is inconclusive. A 29-year-old female with chronic WAD was evaluated using goniometry, the visual analog scale (VAS), and the neck disability index (NDI). She displayed reduced neck mobility, local neck pain associated with cervicogenic headache, and neck-related disability. The intervention lasted 6 weeks, involving two 40 min weekly sessions. The exercise programme incorporated cervical spine-specific exercises, including range of motion, postural endurance, and muscle strengthening, as well as sensorimotor exercises targeting kinaesthetic sense, eye movement control, and eye-head coordination. The outcome measures reflected the resolution of symptoms and physical impairments. The patient experienced significant improvements in cervical mobility, as she regained a full range of movement in all planes. The patient also demonstrated amelioration in both pain and cervical function states. The VAS score dropped from 6/10 to 2/10; likewise, the NDI score decreased from 58% to 22% at the end of the treatment. Our observations suggest that a rehabilitation programme retraining both the cervical musculature and sensorimotor control may be effective in reducing pain and disability in people with chronic WAD. Further research is required to determine the optimal exercise programme for managing symptoms chronicity in people with WAD.

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Key Words: Chronic Whiplash-associated Disorder, Rehabilitation, Therapeutic Exercise

INTRODUCTION

Whiplash often occurs following motor vehicle accidents, involving an energy transfer mechanism affecting the neck and head (Godek, 2020). This can lead to bony or soft tissue injuries and subsequent clinical manifestations termed whiplash-associated disorders (WAD) (Godek, 2020). WAD primarily entails neck pain, muscle spasm, and reduced cervical spine mobility. Other symptoms may affect the head, shoulders, arms, thoracic, and lumbar regions, including headaches, dizziness, visual/cognitive issues, altered sensation, and muscle weakness (Gwilym & Stace, 2015). However, impairment severity varies greatly among individuals (Gwilym & Stace, 2015).

People remaining symptomatic beyond three months post-injury have chronic WAD, a challenging condition for healthcare professionals (Carroll et al., 2008; Sterling et al., 2010). While WAD symptoms typically improve in the first two to three months post-injury, recent research suggests about 50% of people who sustain whiplash injury will not fully recover, developing chronic pain within a year (Carroll et al., 2008; Sterling et al., 2010). Acute injury treatments yield minor effects, and no management strategy prevents chronic disability development (Sterling & Kenardy, 2011). Chronic symptoms reduce patients' quality of life, limiting social participation, functional tasks, and hobbies (de Zoete et al., 2022).

Recently, a substantial body of research investigated the movement and sensorimotor disturbances in individuals with chronic WAD (De Pauw et al., 2018; Mazaheri et al., 2021; Reddy et al., 2021; Treleaven, 2017). Loss of movement, morphological changes in the neck muscles, altered muscle recruitment patterns, decreased muscle strength, and proprioceptive deficits (joint repositioning errors and poor postural control) were reported irrespective of the pain, disability, and recovery levels (De Pauw et al., 2018; Mazaheri et al., 2021; Reddy et al., 2021; Treleaven, 2017). Recent studies also suggest impaired cervical proprioception might be one of the reasons why pain continues and becomes persistent in people with whiplash (Daenen et al., 2013; Treleaven, 2011).

Physical rehabilitation plays a crucial role in the management of chronic WAD, alleviating symptoms and improving cervical function to reduce recurrent episodic pain (State Insurance Regulatory Authority, 2014). Based on evidence, active treatment methods are preferred over passive approaches (Teasell et al., 2010). Although there is no standardised rehabilitation protocol, exercise therapy is the most recommended treatment option (Teasell et al., 2010). Specific exercises focusing on cervical strength, endurance, flexibility, and posture have shown promise in reducing pain and disability (State Insurance Regulatory Authority, 2014). Evidence also suggests that rehabilitation programmes inclusive of sensorimotor training might be efficacious for managing such conditions (Sremakaew et al., 2018).

Correspondingly, findings of recent systematic reviews indicate that programmes combining cervical exercises and proprioceptive training could have an additional beneficial effect on people with chronic WAD in terms of pain relief and improved cervical function (Chrcanovic et al., 2022; Martin-Gomez et al., 2019; Petersen et al., 2013). However, these studies have little supporting evidence; thus, further research is needed to determine the clinical significance of such exercise protocols in reducing symptoms for people with chronic WAD (Chrcanovic et al., 2022; Martin-Gomez et al., 2019; Petersen et al., 2013).

The purpose of this case report was to implement a rehabilitation programme retraining both the cervical musculature and sensorimotor control in a person with chronic WAD while describing its outcomes in relation to the identified impairments associated with the long-term sequelae of whiplash injury and symptom chronicity.

METHODS

Patient description

A 29-year-old female sustained a high-speed motor vehicle accident (> 45 mph), resulting in a neck injury with symptoms of pain, muscle spasm, and soreness. Magnetic resonance imaging ruled out fractures or instability but showed a loss of normal cervical lordosis. The patient was diagnosed with WAD and initially treated with a soft collar, analgesics, and anti-inflammatory drugs. However, her symptoms persisted for nearly 5 months, leading to the transition to chronic WAD and a referral for physiotherapy.

The patient's chronic symptoms included cervical and upper thoracic pain, stiffness, muscle spasm, and headaches, with no upper extremity symptoms. Her medical history was devoid of chronic illnesses, prior neck problems, or surgeries, and she had a sedentary job as a bank teller. Post-accident, her symptoms worsened at work, leading to reduced productivity and occasional absenteeism. Her main rehabilitation goals were symptom reduction and preventing further deterioration.

Examination procedures

A baseline physical examination was conducted before and immediately after treatment, encompassing head position and posture observation, tender points palpation, cervical range of motion assessment, and neuromuscular testing (Blanpied et al., 2017; Jull et al., 2018).

The initial cervical posture analysis revealed a forward head translation and rounded shoulders, indicative of biomechanical neuromuscular imbalances similar to upper crossed syndrome (Chang et al., 2023; Jull et al., 2018; Shaghayeghfard et al., 2016). Palpation uncovered tightness and tenderness in the suboccipital, upper trapezius, levator scapulae, sternocleidomastoid, and pectoralis muscles (Jull et al., 2018; Shaghayeghfard et al., 2016). It also identified lengthened and tender serratus anterior and scapular retractor muscles (Jull et al., 2018; Shaghayeghfard et al., 2016). Palpation-induced provocation of the posterior cervical fascia and joints worsened cervicogenic headaches (Jull et al., 2018; Shaghayeghfard et al., 2016).

Cervical range of motion is a valuable diagnostic tool and treatment efficacy measure in neck pain research (Stenneberg et al., 2017). The patient's cervical range of motion was assessed in a seated position using a goniometer (Clarkson, 2020), revealing mobility deficits with significant reductions in neck motion: 30° flexion, 20° extension, 25° right and left rotation, and 20° right and left lateral flexion. At the end ranges, the patient reported stiffness and heightened head and neck pain.

Manual muscle testing in a supine position (Clarkson, 2020) showed weakness in the cervical flexors, extensors, and rotators, alongside restricted range and pain experienced during all cervical movements with a grade 3–/5 (partial range of motion against gravity). The neurological assessment revealed normal reflexes, and sensory, and cranial nerve function (Rushton et al., 2014). Diagnostic testing for cervical radicular pain including the distraction and Spurling's tests, which demonstrate good sensitivity and specificity (Thoomes et al., 2018), were negative, ruling out cervical spine neurological involvement.

Specific scales and measures

The testing procedures included various measurement instruments. The visual analogue pain scale (VAS) and the neck disability index (NDI) assessed pain intensity and disability level, respectively (Childress & Stuek, 2020).

The VAS was used to measure the intensity of self-perceived pain and distress. The VAS is a 10 cm line, oriented vertically or horizontally, with one end representing "no pain" and the other end representing "worst pain imaginable", and people can mark their daily actual pain, worst pain, and minimal pain (Modarresi et al., 2021; Young et al., 2019). The VAS is widely used due to its simplicity and good psychometric properties, and it is the criterion standard for new rating methods (Childress & Stuek, 2020, Modarresi et al., 2022). The patient reported resting pain at 6/10 and worst pain at 8/10 in the mid-cervical and upper thoracic spine.

The NDI is a widely used tool to assess cervical-related disabilities (Modarresi et al., 2022). It assesses disability and activity limitations attributed to neck pain with 10 items, including personal care, lifting, reading, headaches, concentration, work status, driving, sleeping, and recreation (Modarresi et al., 2022; Pontes-Silva et al., 2021). Each item scores from zero for "no disability" to five "complete disability" (Modarresi et al., 2022; Pontes-Silva et al., 2021). The total score on the NDI can be expressed as a percentage or a raw score out of 50, with high scores reflecting greater disability (Modarresi, et al., 2022; Pontes-Silva et al., 2021). It is the most valid and reliable neck-specific functional measurement tool (Young et al., 2010). The patient had an initial NDI score of 58%, indicating significant neck-related disability.

Diagnosis and prognosis

According to the Quebec Task Force classification, the patient had chronic WAD grade 2, denoting localised neck pain, headaches, and reduced neck mobility without structural damage (Freeman et al., 1998). The WAD grade, VAS, and NDI scores reliably reflect injury severity, but the VAS and NDI are superior prognostic indicators compared to the WAD grade (Angst et al., 2014; Borenstein et al., 2010). The patient's high initial self-reported pain intensity (VAS scores ≥ 5/10) and disability (NDI score > 40/100) suggest a potentially poor prognosis, as these factors often lead to prolonged pain and disability after a whiplash injury (Angst et al., 2014; Borenstein et al., 2010). Nevertheless, the patient had positive recovery expectations, a significant factor linked to improved outcomes (Ferrari & Louw, 2011).

Interventions

The intervention period was six weeks, with two 40 min sessions each week, to deliver a comprehensive programme targeting the cervical musculoskeletal and sensorimotor systems. Cervical training encompassed range of motion, isometric, postural endurance, and strengthening exercises for the neck and scapular muscles. Sensorimotor exercises focused on kinaesthetic sense, eye movement control, and eye-head coordination. The programme employed was similar to the one described by Battal et al. (2021) and Jull et al. (2018). Rehabilitation advanced as the patient met the target at each level (see Appendix A for exercise prescription details). The patient did not receive additional neck-related procedures while undergoing treatment, but regular medication was not withheld.

Cervical spine exercises aim to restore muscle strength and function, improve range of motion, and reduce pain for daily activities and work tasks (Battal et al., 2021; Jull et al., 2018). The treatment involved range of motion exercises to improve neck posture and mobility (Battal et al., 2021; Jull et al., 2018). These exercises targeted movement restrictions in craniocervical flexion, extension, rotation, and lateral flexion in various positions (Battal et al., 2021; Jull et al., 2018). Scapular and deep neck stabiliser exercises aimed to enhance muscle strength, endurance, and control, with a focus on deep neck flexor (DNF) activation and holding capacity (Battal et al., 2021; Jull et al., 2018). The treatment also included exercises that emphasised coordination between the deep and superficial cervical flexors in movement patterning and functional tasks, co-contraction of the cervical flexors and extensors, correction of cervical spine alignment, and training craniocervical extensors and rotators in a neutral position (Battal et al., 2021; Jull et al., 2018).

Cervical proprioception training linked the sensorimotor system of the neck with the oculomotor and vestibular systems to reduce pain, enhance muscle function, and improve cervical kinaesthetic awareness (Battal et al., 2021; Jull et al., 2018). Oculomotor control training included eye follow, gaze stability, and eye-head coordination exercises. In eye follow exercises, the patient tracked a moving target with her eyes while keeping her head still with a neutral cervical spine. Gaze stability exercises involved fixing the gaze on a target while actively moving the cervical spine (flexion, extension, and rotation) (Battal et al., 2021; Jull et al., 2018). These exercises progressed by increasing speed, range, and changing visual targets. Lastly, eye-head coordination exercises required the patient to move her eyes and head in the same direction to focus on a target. Progressions included moving the eyes first, then the head, and moving the eyes and head in opposite directions (Battal et al., 2021; Jull et al., 2018).

It is crucial to ensure the exercise programme does not worsen pain or headaches (Battal et al., 2021; Jull et al., 2018). If symptoms worsen, attempt tasks in more supported positions and introduce exercises gradually (Battal et al., 2021; Jull et al., 2018). Start with fewer repetitions from five increasing to 10 (Battal et al., 2021; Jull et al., 2018). Perform exercises with precision and continuous adjustments, gradually increasing speed and range based on the patient's capacity (Battal et al., 2021; Jull et al., 2018).

RESULTS

After completing rehabilitation, the patient's assessment showed symptom resolution and improved physical condition. The patient experienced increased cervical mobility in all directions, with full pain-free range of motion in flexion, lateral flexion, extension, and rotation. Cervical muscle strength and posture also improved, achieving a grade 4 in manual muscle testing for all neck movements.

Furthermore, the primary outcome measures, the VAS and NDI, showed noticeable improvements. The VAS resting pain score dropped from 6/10 to 2/10, indicating reduced pain. The NDI questionnaire score decreased from 58% to 22%, signifying an 18-point reduction in neck-related disability and better cervical spine function.

DISCUSSION

The purpose of this case report was to describe an exercise programme retraining both the cervical muscular system and sensorimotor control for a patient with chronic WAD. The patient's cervical mobility, pain, and functional performance were assessed before and after the six-week intervention period using goniometry, and the VAS and NDI. All outcome measures improved upon reassessment when compared to baseline measures, with particular improvements in range of motion, pain, and performance of daily activities.

Following the intervention, the VAS score decreased from 6/10 to 2/10, indicating an improvement in the patient's pain status. The patient also displayed noticeable improvements in cervical mobility, showing a full range of motion without pain or stiffness. These findings suggest that treatments focusing on cervical spine exercises and proprioceptive training may help restore painful segmental movement loss and alleviate pain in chronic WAD.

Previous research supports combining cervical proprioceptive training, range of motion exercises, and strength training for chronic WAD patients (Fredin & Lorås, 2017; Senarath et al., 2023; Southerst et al., 2016; Sterling et al., 2014). These approaches lead to improved outcomes, including reduced medication use, pain relief, enhanced sensorimotor function, and improved cervical movement (Fredin & Lorås, 2017; Senarath et al., 2023; Southerst et al., 2016; Sterling et al., 2014).

Recent studies also report that low-load exercise programmes targeting strength, motor control, and sensorimotor function have beneficial effects on neck pain (Astrup & Gyntelberg, 2022; de Zoete et al., 2023; Ludvigsson et al., 2020). Specific low-load training of the DNF had an immediate local mechanical hypoalgesic effect on painful zygapophyseal joints, enhancing cervical neuromuscular control, posture, and function (Amalina

& Setiawati, 2021; Ashfaq & Riaz, 2021; Astrup et al., 2021; Jull et al., 2009; Kim & Kwag, 2016; Rahnama et al., 2023; Sterling, 2011; Treleaven et al., 2016). Cervical spine mobilisation also activates the DNF, leading to greater symptomatic improvement in individuals with higher levels of pain and disability associated with chronic WAD (Bexander & Hodges, 2019; Lindstrøm et al., 2011; Malmström et al., 2013; Meisingset et al., 2015; Moustafa et al., 2022; Seok et al., 2019).

It has been suggested that chronic WAD may disrupt cervical sensorimotor function, altering muscle spindle sensitivity, afferent input, and motor control strategies (Bexander & Hodges, 2019; Lindstrøm et al., 2011; Malmström et al., 2013; Meisingset et al., 2015; Moustafa et al., 2022; Seok et al., 2019). This leads to reduced activity in painful deep neck muscles, causing an increase in superficial muscle activity with delayed relaxation, further affecting cervical proprioception (Bexander & Hodges, 2019; Lindstrøm et al., 2011; Malmström et al., 2013; Meisingset et al., 2015; Moustafa et al., 2022; Seok et al., 2019). To address this, training the inhibited deep neck muscles (semispinalis cervicis, cervical multifidus, longus colli, and longus capitis) can reduce the activity of the overstimulated superficial muscles (sternocleidomastoid and scalene) through reciprocal inhibition (Bexander & Hodges, 2019; Lindstrøm et al., 2011; Malmström et al., 2013; Meisingset et al., 2015; Moustafa et al., 2022; Seok et al., 2019). This, in turn, can alleviate muscle spasm, improve cervical proprioception, and support counteraction of cervical lordosis increment, often seen in forward head posture, helping to maintain proper posture and equilibrium (Borisut et al., 2013; Mahmoud et al., 2019; Petersen et al., 2013). Ultimately, these factors can contribute to symptom reduction in chronic WAD patients (Borisut et al., 2013; Mahmoud et al., 2019; Petersen et al., 2013).

The literature suggests that exercises targeting deep cervical muscles and sensorimotor function can enhance muscle spindle function (Artz et al., 2015). Retraining the inhibited DNF and the deep suboccipital muscles will activate their muscle spindles, increasing sensitivity and discharge (Artz et al., 2015). This improves cervical afferent input and sensorimotor integration into the central nervous system, enhancing motor unit recruitment, firing frequency, and intermuscular coordination (Artz et al., 2015). Reprogramming firing of cervical afferents promotes motor control and normalises joint stresses, resulting in positive changes in cervical proprioception, mobility, and pain (Artz et al., 2015). Thus, a specific exercise regimen reprogramming cervical joint receptors and muscle spindles can positively affect structures likely causing chronic WAD symptoms and address associated cervical spine impairments (Artz et al., 2015).

The patient's NDI score decreased from 58% to 22% post-treatment, meeting the criteria for significant improvement (at least a 10% reduction) (Young et al., 2010). This also reflects a 36% improvement in neck-related functional performance, signifying meaningful enhancement in cervical spine function (Young et al., 2010). However, the NDI score did not reach 0%, indicating some lingering physical impairment. Continuing the rehabilitation programme with advanced exercises is warranted to address the remaining disablement (Young et al., 2010).

The positive outcome may result from improved cervical pain and mobility. These interventions appear effective for reducing chronic whiplash symptoms, limiting neck-related disability, and enhancing muscular performance in chronic WAD. Recent randomised control trials (Landén Ludvigsson et al., 2019; Ludvigsson et al., 2015; Peterson et al., 2021; Ris et al., 2016) and systematic reviews (Leaver et al., 2010; Rushton et al., 2011; Shaw et al., 2010) support active cervical exercise regimens for pain relief and reduced post-injury disability. These studies used various exercises, including range of motion, strengthening, coordination, stabilisation, functional capacity, and proprioception (Landén Ludvigsson et al., 2019; Ludvigsson et al., 2015; Peterson et al., 2021; Ris et al., 2016). A randomised control trial showed that combining proprioceptive training with conventional physiotherapy is more effective in improving neck disability, underscoring the importance of sensorimotor training in managing chronic whiplash symptoms (Sremakaew et al., 2018).

However, a randomised control trial (Michaleff et al., 2014) also concluded that simple advice proves just as efficacious as a more extensive exercise regimen. The therapeutic impact of exercise tends to be modest and it remains unclear which type of exercise is more effective or whether specific exercises are more effective than general activity or basic advice to stay active (Sterling et al., 2019). Nevertheless, the mainstay of management for chronic WAD is exercise, with other studies (Côté et al., 2016; Gross et al., 2015; Wong et al., 2016) emphasising the superiority of active exercise over soft collar use and rest.

In addition to the primary outcomes, cervical strength and posture also improved. The patient's manual muscle testing score increased from grade 2 to 4 in all cervical movements, and forward head posture and shoulder protraction visibly decreased. Research indicates that interventions addressing proprioception and cervical motor dysfunction yield similar results in individuals with neck pain and forward head posture (Petersen et al., 2013; Sheikhhoseini et al., 2018). Training the weakened deep neck stabilisers, particularly the DNF, enhances strength, endurance, and the ability to fine-tune head posture and neck awareness through a feedback loop (Battal et al., 2021).

CONCLUSION

In conclusion, our observations suggest that a comprehensive exercise programme, targeting the cervical muscles and sensorimotor control, can reduce pain and disability, and improve cervical motion in chronic WAD. However, general inferences cannot be drawn from a single case report, and further research is needed to confirm the clinical significance and long-term clinical effectiveness of these interventions for chronic WAD patients.

KEY POINTS

1. Effective rehabilitation: This case report demonstrates that a comprehensive rehabilitation programme, involving cervical exercises and sensorimotor training, significantly improved cervical mobility, reduced pain (VAS score), and enhanced neck-related functionality (NDI score) in people with chronic WAD.

2. Consistent with research: Findings align with existing research supporting the effectiveness of combining cervical exercises and proprioceptive training for pain relief, improved cervical function, and reduced medication use in people with chronic WAD.
3. Tailored treatment importance: The case report emphasises the significance of tailored exercises targeting deep cervical muscles and sensorimotor control, which can positively affect structures responsible for chronic WAD symptoms.
4. Call for further study: Despite promising results, the study highlights the need for additional research to confirm the clinical significance and long-term effectiveness of these interventions. A single case report cannot provide generalised conclusions, warranting more extensive studies for validation.

DISCLOSURES

This research was funded by Holy Family University, which provided financial support to facilitate the execution of the study. The university played no role in the design, conduct, or interpretation of the research and had no influence on the study's outcomes beyond providing financial resources. The authors declare that they have no financial, personal, or professional conflicts of interests that could have influenced the design, execution, or interpretation of this research. There are no affiliations or involvements with any entities or organisations that could be perceived as having a potential conflict of interests.

PERMISSIONS

Ethical approval for this study was obtained from the Lebanese Hospital Geitaoui-University Medical Center (LHG-UMC) Institutional Review Board (IRB) (approval number 2023-IRB-05). In accordance with ethical guidelines, informed consent was obtained from all participants involved in this study.

CONTRIBUTIONS OF AUTHORS

The authors confirm contribution to the paper as follows: Design conceptualisation and methodology, GB and BHB; investigation, data collection and analysis, GB; writing – original draft preparation, GB; writing – review and editing, GB and BHB; supervision and funding acquisition, BHB.

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Appendix A

EXERCISE REGIMEN

Table A1

Training Programme – Sessions One to Four

	Exercise	Description	Targeted repetitions Purpose
Active range of motion training	Supine chin tuck	The patient is supine with a pillow under their neck and knees bent. They retract their chin as far as possible focusing on the posterior translation of the head; it is a gentle controlled nodding action	3 sets of 10 reps each side; Movement held at end range for 10–20 s Restore the regional and segmental range of cervical movement as well as improve the pain state and resting posture
	Supine head extension	The patient practices neck extension with minimal craniocervical extension by pressing the back of the head against the bed while visualising a curling-back action. The patient is instructed to avoid either lifting the chin (activates the multifidus/semispinalis muscles) or chin retraction (activates the deep neck flexors)	Cervical spine mobilisation activates the inhibited deep stabilisers allowing them to engage more effectively during the training exercises
	Supine head rotation	The patient gently turns their head from one side to the other, progressively aiming to turn far enough to align their chin with their shoulder	
	Supine head lateral flexion	The patient gently tilts their head towards the shoulder, progressively aiming to drop the ear further towards the shoulder	
Deep neck stabiliser training	Standing chin tuck	The patient retracts their chin as far as possible focusing on the posterior translation of the head; it is a gentle controlled nodding action	3 sets of 10 reps each side; Contraction held at end range for 10 s Train the inhibited deep stabilisers, in particular DNF activation and holding capacity. Learn the correct movement and train to hold the contraction with/out feedback in progressively more difficult inner-range positions
	Standing chin tuck with extension	The patient retracts their chin as far as possible focusing on posterior translation while simultaneously extending the lower cervical spine	Train the interaction between deep and superficial cervical flexors in controlled head movement through the range of extension and return to neutral
	Standing chin tuck with lateral flexion	The patient retracts their chin as far as possible focusing on posterior translation while simultaneously bending the head to the side	Chin tucks are held at different end ranges to activate the DNF through active cervical mobilisation and to train co-contraction of the deep cervical flexors/extensors in movement patterning and functional tasks
	Standing chin tuck with rotation	The patient retracts their chin as far as possible focusing on posterior translation while simultaneously rotating the head	
	Standing chin tuck combined with ipsilateral rotation and side flexion	The patient retracts their chin as far as possible focusing on posterior translation while simultaneously bending the head and rotating it to the same side	
Oculomotor exercises	Eye follow, gaze stability, and eye-head coordination exercise	While keeping the head still in a chin tuck, the eyes follow a target, with slow speed While fixing the eyes on a single target, the head moves while maintaining the chin tuck	3 sets of 10 reps in vertical and horizontal directions The goal is to activate the inhibited DNF and the deep suboccipital muscles to link the sensorimotor system of the neck with the oculomotor and vestibular systems to improve cervical position sense

Note. DNF = deep neck flexors; reps = repetitions.

Adapted from Sremakaew et al. (2018) and Battal et al. (2021).

Table A2

Training programme – Sessions five to eight

	Exercise	Description	Targeted repetitions Purpose
Active range of motion training	Sitting head nod and extension	The patient gently rolls their head back to look up towards the ceiling, and then bends the head towards the chest, leading the movement with the chin	3 sets of 10 reps each side; Movement held at end range for 10–20 s Restore the regional and segmental range of cervical movement as well as improve the pain state and resting posture Cervical spine mobilisation activates the inhibited deep stabilisers allowing them to engage more effectively during the training exercises
	Sitting head lateral flexion	The patient gently tilts their head towards the shoulder, progressively aiming to drop the ear further towards the shoulder	
	Sitting head rotation	The patient gently turns their head from one side to the other, progressively aiming to see the wall in line with the shoulder	
Deep neck stabiliser training	Auto resistive Standing chin tuck	The patient retracts their chin isometrically against a towel as far as possible focusing on posterior translation of the head	3 sets of 10 reps each side; Contraction held at end range for 10 s The deep neck stabilisers are being stimulated via sensory motor training. The towels provide an unstable surface to elicit automatic stabilisation reactions that cannot be trained automatically (co-contraction of deep neck flexors and extensors). Thus, this increases the endurance and strength of those inhibited muscles by training craniocervical extensors and rotators isometrically with the cervical spine in a neutral position
	Auto resistive Standing chin tuck with extension	The patient extends their lower cervical spine while simultaneously keeping the craniocervical region in a neutral position	
	Auto resistive Standing chin tuck with lateral flexion	The patient retracts their chin isometrically against a towel while simultaneously bending the head to the side	
	Auto resistive Standing chin tuck with rotation	The patient retracts their chin isometrically against a towel while simultaneously rotating the head	
Oculomotor exercises	Eye follow, gaze stability, and eye-head coordination exercise	Eyes leading first to the target followed by the head in the same direction while holding the chin tuck Eyes following a target with the neck in 45° of torsion while holding the chin tuck	3 sets of 10 reps in vertical and horizontal directions The goal is to activate the inhibited DNF and the deep suboccipital muscles to link the sensorimotor system of the neck with the oculomotor and vestibular systems to improve cervical position sense

Note. DNF = deep neck flexors; reps = repetitions.

Adapted from Sremakaew et al. (2018) and Battal et al. (2021).

Table A3

Training Programme – Sessions Nine to 12

	Exercise	Description	Targeted repetitions Purpose
Active range of motion training	Four-point kneeling chin tuck	The lower back, thoracic, and cervical spines are held in neutral alignment, and the scapulae are stabilised in a neutral position. The patient is instructed to tuck the chin as far as possible focusing on the posterior translation of the head. All the motion is focused on the craniocervical region, with the rest of the cervical spine held in neutral	3 sets of 10 reps each side; Movement held at end range for 10–20 s Restore the regional and segmental range of cervical movement as well as improve the pain state and resting posture Cervical spine mobilisation activates the inhibited deep stabilisers allowing them to engage more effectively during the training exercises
	Four-point kneeling head flexion and extension	The patient slowly looks up toward the ceiling as far as they can go. Then, slowly bends the neck as far as possible aiming to touch the chest. The movement is led with a chin tuck	These exercises focus on mobilising the upper cervical joints. Thus, the craniocervical region is mobilised while the rest of the cervical spine is maintained in a neutral position.
	Four-point kneeling upper cervical rotation	The patient tucks the chin while simultaneously rotating the head. The movement is limited to less than 40° focusing the rotation to the craniocervical region to activate the obliquus capitis superior and inferior muscles	
	Four-point kneeling cervical extension curl from flexion to neutral	Starting from a flexed position the patient curls the neck backward extending it to neutral without lifting the chin. There should be as little head nodding or chin retraction as possible	These exercises reverse the focus on the movement in the rest of the neck rather than the upper cervical joints. The craniocervical region is maintained in a neutral position, and the patient extends the rest of the cervical spine, focusing on the semispinalis cervicis/multifidus groups to produce the motion
	Four-point kneeling full cervical extension	Starting from a flexed position the patient curls the neck backward to achieve a fuller range of extension without lifting the chin. There should be as little head nodding or chin retraction as possible	Train the deep cervical extensors and flexors to stabilise the upper cervical joints in a neutral position while the more superficial cranial extensors initiate the movement.
	Four-point kneeling chin tuck combined with arm raise	The patient is instructed to tuck the chin as far as possible focusing on posterior translation of the head. Then, slowly alternate arm raising	Incorporates deep flexor training with scapular training, neck-arm coordination, and a motor control and endurance component. Also, emphasises activation of the hypomobile cervicothoracic region
	Four-point kneeling head rotation combined with arm raise	The patient actively rotates the head while alternately elevating the arms	Incorporates deep flexor training with scapular training, neck-arm coordination, and a motor control and endurance component. Also, emphasises activation of the hypomobile cervicothoracic region
	Sitting diagonals	In sitting the patient looks down and tries to place their chin behind one clavicle, then looks up and away to the opposite side (extension plus rotation). The pattern is retraced to the starting point, to be repeated beginning with the opposite shoulder. This cross pattern can be incorporated with eye movement by having the patient initiate each movement with their eyes, immediately followed by movement of the head in the same direction	Create kinaesthetic awareness and coordinated muscle activity in movements that are closer to those of daily living. Hence, coordinating the activities of multiple cervical joints in angular motions

	Exercise	Description	Targeted repetitions Purpose
Deep neck stabiliser training	Auto elongation exercise	The patient stands against the wall, only their head and shoulders in contact with it. Then, they actively perform an occipital lift to tuck the chin and lengthen the back of the neck, by sliding the head toward the ceiling and pressing the shoulders against the wall to retract them	3 sets of 10 repetitions each side; Contraction held at end range for 10 s Participant trains to actively correct and hold a neutral spinal and correct scapular posture.
	Forehead vertical ball roll	The patient uses their forehead to roll a small ball up and down against a wall using short nodding movements while maintaining a chin tuck all the time	The balls provide an unstable surface to activate proprioceptors in the inhibited deep cervicocephalic muscles. The latter will increase their neuromuscular efficiency and endurance. While the subject is training to maintain a neutral scapulothoracic and cervical posture, segmental variations will occur to protect and rearrange the muscle length back to normal
	Forehead horizontal ball roll	The patient uses their forehead to roll a small ball horizontally, against a wall to rotate the neck while maintaining chin tuck all the time	
	Vertical ball roll with the back of the head	The patient uses the back of their head to roll a small ball up and down against a wall using short nodding movements while maintaining chin tuck all the time	
	Horizontal ball roll with the back of the head	The patient uses the back of their head to roll a small ball up and down against a wall using short nodding movements while maintaining chin tuck all the time	
Oculomotor exercises	Eye follow, gaze stability, and eye-head coordination exercise	Eyes leading first to the target followed by the head moving in the opposite direction while holding the chin tuck all the time	3 sets of 10 reps in vertical and horizontal directions The goal is to activate the inhibited DNF and the deep suboccipital muscles to link the sensorimotor system of the neck with the oculomotor and vestibular systems to improve cervical position sense

Note. DNF = deep neck flexors; reps = repetitions.

Adapted from Sremakaew et al. (2018) and Battal et al. (2021).