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"Postural Alignment First, Symptom Tailored" Integrated Pathway as a Multimodal Peripheral Intervention Strategy for Pain and Cervical Disease (Part 2)

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Abstract

Chronic cervicogenic syndromes frequently arise from interrelated biomechanical misalignment, neuromuscular dyscoordination, and autonomic dysregulation. Building on Part 1, this review (Part 2) details the clinical implementation of the "Postural Alignment First, Symptom Tailored" (PAST) Pathway in perioperative and chronic pain settings.

A four-stage diagnostic and treatment algorithm was developed encompassing postural realignment, load transfer assessment, neuro-myofascial integration, and autonomic evaluation. Core indicators include sagittal vertical axis (SVA), deep neck flexor (DNF) endurance, and heart rate variability (LF/HF ratio). A stratified decision-making matrix was constructed to guide interventions tailored by posture phenotype, symptom severity, and autonomic state.

The PAST model facilitates outpatient stratification and phased interventions with measurable outcomes. It enables upstream correction of biomechanical and neuromodulatory dysfunctions and supports individualized treatment for cervical pain, dizziness, tinnitus, and insomnia.

The PAST pathway provides a reproducible, scalable, and precision-oriented intervention model. Its integrated structure-function-autonomic framework enhances clinical efficacy and lays the foundation for algorithm-driven applications in translational perioperative medicine.

Keywords

PASTPathway, Pain, Cervicogenic disorders, Autonomic dysfunction, Multimodal intervention strategy

Introduction

The first part of this research introduced the "Postural Alignment First, Symptom Tailored" (PAST) Integrated Pathway as a novel, structured, and multimodal peripheral intervention model for managing cervicogenic disorders and related pain syndromes. Rooted in neuromechanical, neurophysiological, and postural rehabilitation principles, the PAST framework emphasizes a staged approach in which biomechanical realignment is prioritized before implementing symptom-specific therapies. This strategy directly addresses the often-overlooked postural etiologies underlying chronic cervical pain and its associated manifestations such as vertigo, tinnitus, sleep disturbances, and sympathetic overactivation.

The PAST pathway is organized into three progressive clinical phases: Postural Priming (P), Adaptive Neuromechanical Rebalancing (A), and Symptom-Targeted Peripheral Modulation (ST). Its innovation lies not only in the logic of phased progression but also in the development of a subtype classification system-PAST-A (posture-dominant), PAST-B (pain-dominant), and PAST-C (central sensitization-dominant)-which allows clinicians to tailor treatment plans while adhering to a consistent mechanistic framework. Quantitative tools such as photographic postural analysis, myofascial trigger point palpation, and vestibulo-ocular reflex testing support clinical decision-making. Part 1 established that correcting cervical postural dysfunction as an initial step leads to broader therapeutic effects compared to symptom-first approaches, laying the theoretical and empirical foundation for applying the PAST model across multiple peripheral intervention modalities.

Building upon this foundation, Part 2 further elaborates the mechanistic rationale and operational structure of the PAST model from a tripartite perspective: postural alignment, neuromuscular function, and autonomic regulation. Specifically, it constructs a four-

dimensional diagnostic framework encompassing the continuum from static alignment to dynamic load distribution, neuromyofascial synergy, and autonomic stabilization. A stage-based intervention matrix is also proposed, encompassing postural correction, deep muscle activation, closed-chain functional integration, and symptom-targeted peripheral modulation. Each stage is accompanied by quantifiable evaluation indices-such as sagittal vertical axis (SVA), deep neck flexor (DNF) endurance, and low-frequency/high-frequency (LF/HF) heart rate variability ratio-ensuring precision in assessment and intervention. Together, these elements support a structured, integrative, and symptom-aligned therapeutic pathway for chronic cervicogenic conditions.

PAST pathway overview of assessment ideas

This scheme follows the principle of "from the outside in, from the static to the dynamic" and quantifies static alignment → dynamic load → neuromuscular function → autonomic nervous system stability in sequence, forming a postural assessment network of "head up, chest out, pillar style" that can be implemented immediately in the outpatient clinic.

Static alignment: Quickly locate the "force abnormal area": The assessment framework of the PAST pathway is based on a diagnostic logic that moves from external to internal and from static to dynamic, emphasising a systematic analysis from structural alignment to functional loading and then to the neuro-myofascial and autonomic regulatory systems. The baseline assessment begins with static alignment, quickly identifying the patient's 'tension breakpoints' and 'postural weak zones' and providing quantitative evidence for subsequent stratified interventions [1,2].

At the structural level, it is recommended to use natural standing full lateral view radiographs (such as EOS or radiographs) to assess key parameters such as C2-C7 SVA, T1 tilt, PILL and the distance between the centre of gravity line and the lateral malleolus. The literature suggests that C2-C7 SVA > 40 mm or T1 tilt < 13° often indicates inadequate sagittal compensation in the cervical spine, which can easily lead to chronic neck pain [3]. In addition, the "three-point vertical line method" is used to assess whether the "earlobe-shoulder tip-femur-ankle" alignment is correct; an earlobe-shoulder tip-anterior angle > 5° suggests a typical forward head posture (FHP) imbalance.

Combining the Foot Posture Index (FPI-6) with the measurement of anterior pelvic tilt can help to identify load imbalances in the "foot-pelvis-spine-cranium" chain. For example, an FPI6 > + 6 and an anterior pelvic tilt > 15° are highly correlated with lumbar-cervical dysfunction and an increased risk of chronic pain [4]. By assessing these indicators at the outpatient level, the PAST pathway achieves a three-dimensional assessment loop of "structure + function + neuromodulation", providing quantifiable evidence for accurate diagnosis and treatment.

Dynamic stress: Discovering "hidden barriers to chain transmission": In the PAST pathway, the second level of assessment from "static to dynamic" is dynamic stress assessment. This focuses on mechanical coordination and muscle group control during movement, with the aim of identifying 'chain imbalances' that are difficult to detect in static structural assessments. This level is particularly important as many patients appear normal on static radiographs but may have potential problems such as broken kinetic chains, delayed control or muscle strength imbalances during functional movements.

Key tools include gait-bone-pelvis-spine coordination analysis using 3D motion capture or IMU sensors. Quantifying quantitative indicators such as the PI fluctuation of pelvic parameters or the lumbar-hip coordination coefficient indicates the presence of a 'tension frame' gap, which is often associated with chronic low back and neck pain [5].

The other key test is the deep neck flexor endurance test (DNF), which has a normal value of more than 38 seconds for men and more than 29 seconds for women; if it is below this threshold or reduced by more than 20%, it indicates inhibition of the deep stabilising muscles, which is common in head extension posture and neuromuscular control disorders [6].

At the same time, ultrasound shear wave elastography to assess gastrocnemius and hamstring elasticity (< 4.5 kPa is considered a functional tension deficiency) can determine whether the lower limb is sufficient to support the spine, thus revealing the transmission barrierin the "lower limb-pelvis-trunk" load chain [7].

Neuro-myofascial function: Locating the "amplifier: In the PAST pathway assessment system, the level of "neuro-myofascial function" serves as a core bridge between postural mechanics and symptom expression, with a focus on identifying hidden signal amplifiers, i.e. muscle and fascial dysfunction, that result in sympathetic activation, arousal sensitisation or hyperpain.

The primary tool is surface electromyography (sEMG), which monitors the electromyographic co-activation of the neck extensors, upper trapezius and serratus anterior during the 'sit-stand-head-up' triad tasks. Studies have shown that a serratus-upper trapezius RMS ratio below 0.6 indicates excessive compensation or muscle strength imbalance in the shoulder girdle, leading to chronic tension and nerve compression in the neck and shoulder region [8].

Secondly, fascial slip ultrasound is used to assess the rate of fascial slip in the thoracic, dorsal or lumbar region. A fascial slip rate of < 0.1 mm/s often indicates

a tendency towards fibrosis and delayed mechanical receptor feedback, which has been shown to be closely associated with chronic pain and arousal dysfunction [9].

Finally, the state of sympathetic activation can be assessed by combining cross-sectional scanning of the longus cervicis muscle with colour Doppler ultrasound of the cervical sympathetic chain. An increase in the thickness of the longus cervicis muscle and a high peak blood flow velocity in the sympathetic chain are often seen in individuals with elevated LF/HF in their nocturnal HRV, suggesting that structural fascial tension may affect the stability of the autonomic nervous system via the sympathetic chain [10].

Assessment of balance-body-vision integration: The 'perceptual hub' linking postural control and neural integration: At the level of 'functional neuromuscular postural control' of the PAST pathway, the coordination of the proprioceptive-vestibular-vision integration system is considered a core aspect in the assessment of postural stability, motor prediction accuracy and central regulatory capacity. This module not only influences an individual's dynamic response to gravity, but also serves as a common pathological basis for symptoms such as CGD, cervicogenic tinnitus and sleep-wake disorders [11].

Firstly, the Balance Error Scoring System (BESS) test uses three postures (heels together, single foot and chevron stance) combined with a hard/soft pad platform to assess the stability of the sensorimotor loop. Studies show that a number of errors greater than 15 is a strong indicator of cerebellar-vestibular-proprioceptive integration disorders, particularly with a sensitivity of up to 78% in patients with cervical spondylosis [12].

Secondly, the head-eye coordination gaze stability test (VOR-cervico-ocular reflex) assesses the phase coupling of "eye-head" tracking using laser dot tracking and a three-axis gyroscope. If the eye-head phase difference is > 20 ms or the offset angle is > 15°, vertigo, eye movements and dynamic blur are likely to occur, indicating inadequate coupling between neck proprioception and the prefrontal cortex [13].

Finally, the centre of gravity trajectory (CoP) during a 5° forward and backward tilt was measured using a tilted foot force plate (dynamic posturography). If the elliptical area was > 200 mm^2 and accompanied by subjective discomfort, it could be confirmed as "postural sensor mismatch of the kinetic chain", which was a sensitive indicator to assess the vestibular imbalance of the kinetic chain in the PAST path.

Assessment of autonomic homeostasis: A physiological window linking postural regulation and sympathetic sensitivity: In the PAST pathway, assessment of 'autonomic homeostasis' is a key link in determining whether postural correction has successfully influenced physiological regulation. This level of assessment comprehensively reflects the balance and dynamic response of the sympathetic-adrenal system through heart rate variability (HRV) analysis, postural stress testing and sweat gland activity measurement.

Firstly, 24-hour HRV monitoring (LF/HF, SDNN) can be used as a tool to assess baseline status. Studies have shown that patients with chronic neck pain are often characterised by persistent sympathetic nervous system tension, often accompanied by symptoms of sympathetic-type insomnia such as difficulty falling asleep and early morning awakenings [14]. This parameter can be monitored continuously using wearable ECG patches, making it feasible for outpatient use.

Secondly, the postural stress HRV test (e.g. 30° forward head tilt held for 2 minutes) is used to induce sympathetic responses. A $\Delta LF/HF \geq 0.5$ indicates a high degree of coupling abnormality between neck proprioceptive regulation and sympathetic activity, meaning that even small postural changes can induce HRV-sensitive fluctuations, which is one of the sensitive indicators for early assessment of the PAST pathway [15].

Complementary tools such as QSART (Quantitative Skin Resistance + Sweat Gland Activity) measure changes in micro-sweat peaks on the dorsum of the foot and lateral malleolus to quantify the effect of postural adjustment on peripheral sympathetic output. If the QSART peak decreases by ≥ 25% after PAST path correction, this indicates a significant reduction in sympathetic output [16].

Combined assessment and stratified decision making: Combined assessment and stratified decision making: Establishing a Four-Dimensional Diagnostic Closed Loop Based on the PAST Pathway.

In the PAST Pathway assessment system, the "combined assessment and stratified decision making" phase is a critical operational node, bridging the initial postural screening to intervention grading. This system, based on the four-dimensional logic of "structure-function-neuroautonomy", constructs two levels of combined assessment characterised by efficiency, quantifiability and clinical applicability.

The first level is the basic outpatient combined assessment (15 minutes) [1], which includes the three-point assessment of the vertical line, Foot Posture Index (FPI-6), pelvic tilt measurement, deep neck flexor endurance (DNF) and CCFT tests, and a 5-minute HRV (sit-to-stand) test. This group is suitable for rapid initial screening of patients with common neck and shoulder

pain and postural abnormalities. If any key parameter (e.g. DNF < 20 seconds, FPI > +6, LF/HF > 2.0) is abnormal, this suggests a potential imbalance in the kinetic chain or sympathetic system and further evaluation should be initiated.

The second level is an anatomical chain assessment (40 minutes), suitable for patients with recurrent episodes or multi-system cervical manifestations (such as CGD, cervicogenic tinnitus, sleep disorders). This includes the integration of EOS whole spine imaging, dynamic gait-pelvic coordination analysis, neck and shoulder SEMG and fascial slip ultrasound, BESS balance testing, VOR eye-head coupling test and 24-hour HRV monitoring. Ultimately, this results in a four-dimensional scoring model (structural/dynamic/neural/autonomic) to provide evidence-based support for individualised postural-dynamic cascade reconstruction pathways [1,17].

Proposals for implementation and quality control: Building a reproducible, traceable and verifiable system for PAST path: In order to ensure the operability of PAST path in clinical practice and its reproducibility in research, it is proposed to establish a standardised implementation and quality control system with four aspects: staff training, data integration, follow-up frequency and scientific research extension.

First, in terms of staffing and operational standards, the multidisciplinary staff (radiographers, physiotherapists, neurophysiologists) involved in the implementation of the pathway should receive uniform training and strict adherence to SOPs should be enforced. Studies have shown that posture images and EMG signals are highly sensitive to operator consistency and that non-standardised procedures can lead to measurement errors [18].

Secondly, the data integration platform recommends the use of HL7-FHIR or JSON standard protocols to connect PACS imaging, HRV recording systems and gait capture platforms. This automatically generates comprehensive cross-system reports, facilitating multidisciplinary consensus decision making and follow-up. Similar integrations have been successfully used in the development of digital musculoskeletal platforms, improving assessment efficiency by over 70% [19].

Thirdly, it is recommended to repeat the assessment of the core indicators (DNF endurance, C2-C7 SVA, HRV-LF/HF) at three key points: week 0, week 8 and week 24, which can be used to monitor the response to the intervention and adjust the trajectory. This scheme can effectively predict the persistence of pain relief and the risk of symptom recurrence.

Finally, at the research level, it is suggested to apply multi-level mixed-effects models in RCT to integrate LF/HF, dynamic coordination and symptom relief (such as VAS, NDI) for analysis to explore the response threshold of each indicator and the best predictive model, supporting the upgrade transformation of the PAST pathway from practice to evidence-based [20].

PAST path integration and hierarchical management process

This protocol is based on three major anatomical and physiological pillars: the 'head-upright-chest-standing' postural alignment structure, the posture-body-skin-fascia coordination network, and the foot-bone-pelvis-spine-cranium dynamic chain coupling mechanism. Studies have shown that prioritising the restoration of sagittal alignment and neuromuscular fascial coordination, followed by targeted intervention for primary symptoms such as pain, dizziness and sleep disturbance, can significantly improve long-term efficacy and reduce recurrence [1,21]. Therefore, the PAST pathway adopts a 'stage-task-indicator' structure, with the first stage (PAST 1 phase) being a rapid stratification that is immediately feasible at the first outpatient visit, suitable for completion of basic assessment and stratification within 0 weeks of the first visit (Table 1).

"PAST 2 phase": Postural correction phase (week 0-6) (Table 2): The first intervention phase of the PAST pathway aims to restore the sagittal alignment foundation of "head up, chest out and spine erect". This is achieved through a triadic strategy of relaxation, alignment and activation aimed at resolving the tension chain imbalance and inhibiting the neural-fascial pathway. The focus of this phase includes

1. Resetting the entire tension chain from distal to proximal.
2. Deep proprioceptive muscle group activation and
3. Achieving periodic feedback evaluation metrics.

"PAST 3 phase": Period of functional integration (weeks 6-12) (Table 3): The aim of this phase is to integrate the multi-layered coordination mechanism of the neural power chain-autonomous system, based on the completion of the initial postural correction, and to restore higher feedforward control and dynamic stability. The core idea is: closed-loop activation → perceptual reconstruction → sympathetic desensitisation → phased quantitative evaluation.

"PAST 4 phase": Symptomatic phase (weeks 12-24) (Table 4): This phase emphasises the introduction of symptomatic intervention only after basic functional indicators such as posture, motor chain and autonomic nervous system have been met. Research has confirmed that if structural interventions are inadequate, there is a risk of overuse of analgesics and invasive treatments [33]. Therefore, the PAST pathway establishes the

Table 1: "PAST 1 phase": Rapid stratification at initial visit (week 0).

Evaluation dimension	Core indicators	Grading threshold	Main tools
static alignment	C2-C7 SVA; T1 Angle; FPI-6	Mild: SVA ≤ 20 mm; moderate: 20-40 mm; severe: > 40 mm	EOS / Long axis X-ray; Foot Posture Index [22]
Dynamic load	Waist-pelvis coordination coefficient; DNF endurance	Moderate if the coordination coefficient is greater than 0.6 and the DNF is greater than 30s.	3D motion capture / IMU sensor; timer [23]
Autonomic function	HRV: LF/HF ratio	Normal: < 1.5; Alert: 1.5-2.5; Imbalance: > 2.5	Wearable ECG patch; HRV analysis software [18]
Complaint rating	VAS / NDI / DHI	Light: VAS < 4; moderate: 4-7; heavy: > 7	Standardized scales: Neck Disability Index et al. [24]

Table 2: Intervention matrix for postural correction (weeks 0-6).

module	concrete measure
Relax the tension and reset [25,26]	-Sartorius + adductor magnus + pectoral fascia: 3 x 30s static stretch
	-Roll or dry needle release, twice a week (Level B+)
Foot-pelvis-spine co-axial correction [27,28]	-FPI-6 > +6: Use dynamic foot pads
	-Anterior pelvic tilt > 15°: pelvic support 4h/day
Neuro-motor activation	-DNF + CCFT 2 x 10 min per day
[1,18,29]	-GPR "station-squat-extension" sequence twice a week x 45min
Stage evaluation index	-SVA decreased by at least 10 mm
[1,18,25,29]	-DNF increased by at least 25%
	-LF/HF decrease ≥ 0.3

Table 3: Intervention matrix for the functional integration period (weeks 6-12).

module	intervention study
Closed chain power chain training [30]	-TRX/Landmine Squats activate lower limb-pelvic-thoracic tension
	- " Spiral gait training: contralateral shoulder belt-pelvic step traction
Re-calibrate the posture [31]	-Laser headlight + random rotating head and neck training, tracking accuracy ± 2°
	-6 weeks of training can significantly reduce DHI and dynamic blur
Autonomic Rebalance [32]	-5s inhale-5s exhale x 5 min + lying down with a lumbar pillow relaxation exercise
	-If LF/HF > 2, vagus nerve stimulation or auricular needle is added
Stage quantitative index	-C2-C7 SVA ≤ 20mm; waist-bone coordination > 0.7
[1,31,32]	- LF/HF < 1.5, VAS < 3, NDI < 15

Table 4: Interventions for Symptom Targeting (Week 12-24)

Type of complaint	Preferred intervention strategy	Enhanced programmes (e.g. not alleviated)	Recommendation level
Chronic neck pain/ headache [34,35,36]	-Maintain GPR + DNF training	-C3-C6 selective nerve root block	Level B, C
	-NSAIDs Use as required (PRN)	-Radiofrequency coagulation (only Level C)	
Cervical vertigo [37,38]	-Eye-head-neck coordination training	-Bow step weighted training + sEMG feedback (reactive gait)	Level A, C
	-Frontal body reaction training	Support vestibular rehabilitation training to improve gait responsiveness and stability, which is more compatible with PAST training.	
Cervical tinnitus [38]	-Jaw-tongue-neck muscle release training	Transcutaneous vagus nerve stimulation (auricular VNS) → Activation of the ascending inhibitory system.	Level B, C
	-Acupuncture stimulation of the auricular point		
Sleep disorders [39-41]	-Sleep hygiene guidance is initiated after HRV assessment	-Melatonin 0.5-2 mg;	Level B, C
	-Respiratory resonance training (5-5 rhythm)	- α2 receptor agonists such as Dex (low dose);	

"symptom-targeting phase" as the fourth stage (week 12-24), with the core principles of "functional stability + minimal dose + targeting" to develop a refined stratified intervention plan.

"PAST 5 phase": Consolidation and re-protection period (6-12 months) (Table 5): This phase is the final link in the PAST pathway and aims to prevent re-establishment of the somatosensory-neurological-dynamic chain imbalance, reduce relapse rates and achieve long-term maintenance of high functional status. Patients with chronic cervical disorders (such as neck pain, CGD, tinnitus, insomnia, etc.) have a higher relapse rate if they lack structural-functional integration

Table 5: Consolidation and re-protection period assessment and intervention plan (6-12 months).

time point	Re-test items	Clinical objectives	Technical support platform	literature reference
June	C2-C7 SVA + HRV-LF/HF + DNF endurance	All indicators remain at Level A-B standard and are not returned to Level C.	Wearable IMU / ECG device	[1]
December	Full dynamic gait analysis + fascial slip rate (ultrasound)	Tension chain continuity recovery was greater than 90% and myofascial slip was greater than 0.12 mm/s.	AI intelligent early warning system (based on HRV + motion data)	[43]

strategies after symptom relief [42]. Therefore, after completing the first three stages (P-A-S) of intervention, the PAST pathway enters the R stage (Reinforcement), where remote monitoring and AI prediction mechanisms reinforce the three dimensions of "tension coherence-sympathetic homeostasis-cognitive integration".

In addition, in order to prevent the recurrence of the "emotion-posture-pain" cycle [44], it is recommended to add a quarterly screening of self-efficacy and sleep quality (PSQI, PSEQ scale) [45], combined with an assessment of the stability of the sympathetic-HPA axis, in order to continuously follow the autonomic nervous adaptation.

Summary of the PAST pathway: An integrated strategy of three-dimensional fusion of structure-function-intervention: PAST Path (Postural Alignment-first, Symptom-tailored Therapy) is a multistep management system proposed for the diagnosis and treatment of chronic cervical disorders, emphasising structural priority, functional integration and symptom orientation. Previous studies [46-49] have shown that when used alone for symptomatic intervention, it often fails to stabilise due to the lack of reconstruction of the "posture-neuromuscular-tendon" foundation, leading to high recurrence rates. PAST considers posture, the kinetic chain and the autonomic nervous system coupling as upstream control elements, thereby establishing a five-step intervention model (PAST 1-5).

When implemented in clinical practice, clinicians must use the three-dimensional structural-functional-neural indicators to quickly determine the patient's level (see table below for indexing) and select treatment modules of varying intensity and resource allocation. At the same time, the pathway includes a 'safety valve' mechanism to avoid premature intervention with high-frequency, CBT or drug treatments before functional standards are reached, thereby reducing the waste of medical resources and the risk of neural sensitivity. Key points in the implementation of the PAST pathway include:

(1) Line first, pain relief later: restoration of the sagittal line can significantly reduce nociceptive signal input, reduce NSAID use and reduce the frequency of RFA. Randomised controlled trials show that 6 weeks of GPR training followed by radiofrequency intervention can improve analgesic persistence [50].

(2) Quantitative control: It is recommended to follow the three-axis indicators SVA (structure) + DNF (muscle control) + LF/HF (sympathetic) at each stage to avoid the subjective misjudgment of "just looking at the pain score" and to ensure the biofeedback closed-loop [1] of the path operation.

(3) Multidisciplinary collaboration: Establish an MDT team from podiatry, physiotherapy, neuroregulation and sleep medicine, and use standardised data interfaces (such as HL7-FHIR) to achieve cross-platform sharing [51] of images, HRV and electrophysiology.

(4) Patient empowerment mechanism: Through the visualised "posture-heart rate-gait" triple parameter trend chart of the exclusive APP, the patient's self-regulation ability and treatment compliance are enhanced, and the long-term recurrence rate control effect is significantly improved [52].

A review of graded evidence for peripheral stimulation techniques in the PAST pathway

Cervicogenic pain, dizziness, tinnitus and sleep disorders are chronic, complex conditions whose pathogenesis often involves an imbalance of the "postural-neurological-fascial-sympathetic" quadruple. Traditional treatments focus on pain relief or neuromodulation, easily overlooking the upstream drivers that trigger abnormal perceptual-sympathetic tension. The PAST (Posture-Alignment first, Symptom-Tailored) pathway suggests: "Priority should be given to restoring sagittal alignment and kinetic chain continuity through peripheral stimulation techniques before any pharmacological or interventional treatment".

The aim of this review is to sort out the peripheral stimulation techniques applicable to each stage of the PAST pathway, classify them into evidence-based grades (A/B/C) according to the results of systematic reviews and RCTs, and propose a therapeutic prediction node and indicator tracking system to assist in precise pathway allocation (Table 6).

Peripheral stimulation intervention strategies with three levels of stratification

Grade I (mild postural disturbance) (Table 7): Objective: This level targets mild postural abnormalities (such as anterior neck and shoulder flexion, mild FHP

Table 6: Definition of evidence level.

Rank	source of evidence	criteria for evaluation
A(tall)	≥ 2 systematic reviews or ≥ 2 multicenter large sample RCT	Results consistent with low risk of bias.
B (centre)	One high-quality RCT or multiple small sample RCTs	Consistency of results was moderate, with possible bias or heterogeneity.
C (low)	Queues, case-control studies, mechanistic tests	The initial data, the sample size is small or the methodology is inadequate.

Table 7: Evidence-based postural intervention techniques for cervical dysfunction.

Intervention techniques	mechanism of action	recommended parameter	Evidence-based grades	Source literature and link
Global Posture Re-education (GPR)	By anatomically stretching the fascial chain and regulating respiration, the tension and sagittal alignment of the thoracic and lumbar fasciae is reshaped to relieve postural pain.	45 min x 2 times per week x 6 weeks	A	[53]
Deep neck flexor pressure biofeedback training	The pressure sensor is used to strengthen DNF-SCM cooperative control, improve proprioceptive input and cervical spine stability.	20 minutes per day x 4 weeks	A	[54]
Thoracic vertebra-pelvic joint laxity	Release the iliac fascia and thoracolumbar junction, improve the rhythm of spinal movement and optimise the upright tension chain.	3 times per week x 2 weeks	B	[55]
Breathing-trunk synchronization training	5-5 Rhythmic resonance breathing training has been used to improve the high frequency (HF) component of HRV, increase vagal tone and improve sympathetic dominance.	10 minutes per day	B	[56]

Table 8: Peripheral pain modulation techniques for cervical dysfunction: Summary of evidence-based approaches

Intervention techniques	mechanism of action	recommended parameter	Evidence-based grades	Source literature and links
Acupuncture (Cervical spine + Ear gate / Shen gate)	By activating the endogenous opioid system (such as beta-endorphin, enkephalin) and the descending pain inhibitory system, neck and shoulder muscle tension and sympathetic hyperactivity were reduced.	2 times per week for 4 weeks	A	[57]
Dry needle combined with manual reduction (MTrPs + joint traction)	The protective muscle contraction induced by myofascial trigger points is removed, restoring the local tension chain and neural recalibration after small joint misalignments.	Once a week for 4 weeks	B	[58]
LLLT / HILT, laser therapy	Low energy laser (LLLT) can activate mitochondrial ATP production and alleviate myogenic inflammation; high energy laser (HILT) is helpful for deep tissue metabolic recovery.	LLLT: 4 J/cm^2; HILT: 10 W	B	[59]
TENS / NMES (neck and back muscles)	Pain transmission was inhibited by stimulating Aβ fibres; local blood flow and muscle activation were increased to improve proprioceptive input.	Frequency 100 Hz, pulse width 200 μs, 30 min per day	C	[60]

and vagal hypotension) and aims to restore sagittal neck and shoulder alignment, muscle group coordination and autonomic balance through non-invasive intervention.

Grade II (postural disturbance + mild to moderate pain) (Table 8): Objective: Building on the initial restoration of sagittal alignment, to continue to rapidly control pain symptoms, reduce sympathetic hyperactivity and relieve increased reflex muscle tone and associated discomfort.

Grade III (severe postural disturbance + central sensitisation) (Table 9): Objective: This level applies to patients with significant postural collapse, electromyographic imbalance, HRV abnormalities and central sensitisation (e.g. widespread tenderness, sleep disturbance). The focus is on rebuilding the sympathetic inhibition threshold, breaking the central amplification loop and laying the foundation for kinetic chain reconstruction and functional integration.

Standard 8-week treatment template: Postural Alignment-Symptom Tailored Standardised (PAST-St) model (Table 10): Based on the three-stage structure of the PAST pathway, this protocol designs an 8-week standardised treatment template that integrates multi-dimensional quantitative assessment such as postural

Table 9: Neuromodulatory interventions for cervical pain and dysfunction: summary of techniques and evidence.

Intervention techniques	mechanism of action	recommended parameter	Evidence-based grades	Source literature and links
Spinal cord electrical stimulation (spinal cord stimulation, scES)	By inhibiting the transmission of pain through the column and posterior root, the regulatory stability between the cortex, spinal cord and ramus system is restored and the base tension of the extensor muscle groups is increased.	30 Hz, 300 μs, 30 min per day	B	[61]
High frequency pulsed radio frequency (C2-C4)	The high-frequency, temperature-controlled electric field is used to target the surface of the dorsal root ganglion and inhibit excessive neuronal discharge, suitable for patients with headaches and tinnitus.	42°C, 120s x 2 rounds	B	[62]
Ear vagus nerve stimulation (taVNS) + transcranial direct current stimulation (tDCS)	Reset of solitary nucleus coeruleus-hypothalamic axis rhythm, amelioration of sympathetic hyperactivity and sleep fragmentation, suitable for chronic pain associated with insomnia.	taVNS: 25 Hz, 200 μs; tDCS: 1 mA, 1 h per day	C	[63]
Heavy load closed chain training + functional electrical stimulation (NMES)	Activate the lower limb closed chain stability and the foot-pelvis-spine tension chain and work with the NMES to strengthen distal force transmission and balance mode reconstruction.	Load 2-3 times body weight, NMES 50 Hz	C	[64]

Table 10: Weekly clinical adjustment plan guided by HRV and postural metrics.

Weekly	Core evaluation indicators	Adjustment and intervention recommendations	Evidence-based support
W0	HRV (LF/HF), cervical spine imaging (SVA), posture photography, and DNF endurance test	The graded assessment (I/II/III) has been made and the appropriate pathway has been inserted; LF/HF > 2.0 → Vagal activation training needs to be increased.	[29,65]
W2	The SVA vertical axis offset decreased by at least 10 mm	If not, thoracic manipulation or low energy laser (LLLT) can be introduced to improve fascial elasticity regulation.	[66,67]
W4	The EMG score of neck and back muscles was coordinated, and HRV-LF/HF fell back < 1.8	If LF/HF remains high, a combination of dry needle and vagus nerve stimulation is recommended to inhibit sympathetic overdischarge.	[26,68,69]
W6	DNF duration > 30s + gait rhythm coordination	If DNF is slow to improve, maintain current training intensity and avoid early overload to induce muscle compensation.	[70]
W8	PSFS (functional goal score) ≥ 6 points; PSQI ≤ 6 points	Those who meet the standard are transferred to the PAST maintenance period; those who do not meet the standard are recommended to extend the cycle by 1 week and strengthen the autonomic nerve intervention module.	[45,71]

Table 11: Core clinical indicators for PAST pathway assessment.

module	Tools and parameters	range of normal value	sensitivity	Clinical value and basis
Sympathetic activity assessment	HRV LF/HF ratio (5-minute recording)	0.8-1.5	★★★★☆	It reflects the change in sympathetic-vagal tension ratio, and LF/HF > 2.0 is an indicator of chronic sympathetic activation and susceptibility to psychosomatic illness [29].
Pose structure to line	The EOS (EOS Imaging) was used to determine C2-C7 SVA	≤ 20 mm	★★★☆☆	Assess the stability of the sagittal plane of the cervical spine and predict the risk of recurrent cervical strain and pain [72].
Muscle group synergistic activation	sEMG RMS Ratio (deep neck flexor muscle / sternocleidomastoid muscle)	≥ 0.6	★★★★☆	The biological feedback objective was used to measure the priority of deep muscle recruitment and the degree of recovery of neck muscle function during the training intervention [66,70].
Central sensitization level	PPT (Pressure pain threshold, kg/cm^2)	≥ 4.0 kg/cm^2	★★★☆☆	The degree of central pain sensitisation was highly correlated with the risk of chronicity and emotional disturbance [73].

assessment, bioelectric index and autonomic nervous state, which is suitable for Grade I~III postural disorders and associated symptoms.

Quantitative monitoring matrix (Table 11): In the management of PAST path standardisation, it is necessary to rely on a combination of highly sensitive indicators to track and monitor four dimensions: autonomic nervous system stability, postural structure, muscular coordination control and central sensitisation, in order to achieve individualised path adjustment and effectiveness assessment.

Recommendations for Future Research

Remote control system

A wearable platform based on IMU (Inertial Measurement Unit) + HRV to achieve dynamic collection of postural-neural indicators and automatic adjustment of training load (biofeedback-based auto-adaptation).

Central sensitisation population mechanism RCT

It is recommended to compare the efficacy of PRF, taVNS and tDCS interventions on neuroplasticity reconstruction and long-term changes in HRV.

Multi-indicator machine learning predictive modelling

Construct a neck pain/CYG recurrence risk model (predictive recurrence algorithm) by combining HRV, sEMG and posture parameters with sleep quality or mood score.

Conclusion

This second part of the study expands upon the foundational PAST pathway by proposing a comprehensive intervention matrix that bridges biomechanical correction, neuromuscular integration, and symptom-targeted peripheral modulation. Through phase-specific strategies-including postural realignment, deep muscle activation, and closed-chain functional retraining-we illustrate how precise peripheral interventions can realign postural structure and restore autonomic balance in patients with chronic cervical pain, dizziness, sleep disturbance, and associated syndromes. The proposed four-level intervention logic and evaluation-feedback framework not only enhance therapeutic precision but also promote sustainable outcomes and interdisciplinary collaboration.

Moreover, by integrating quantifiable biomechanical indices (e.g., craniovertebral angle, deep neck flexor endurance), neurofunctional parameters (e.g., HRV-based LF/HF ratio), and individualized symptom codes (PAST-A/B/C staging), the model enables stratified management that is both repeatable and scalable across clinical settings.

Looking forward, the PAST pathway holds significant translational potential for implementation in outpatient rehabilitation, pain management, and autonomic disorder clinics. Further research-including randomized controlled trials and neuroimaging-based mechanistic studies-will be critical for validating its efficacy and optimizing algorithm-driven personalization. Ultimately, this framework offers a structured yet flexible clinical paradigm for addressing the multifaceted pathophysiology of cervicogenic and posture-related disorders.

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Conflict of Interest

None.

Presentation

None Declared.

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