

FROM CERVICAL IMPAIRMENT TO SYSTEMIC FUNCTIONAL DISTURBANCE: EXPLORING CRANIOFACIAL AND PSYCHOSOCIAL PATHWAYS

Georgiana-Brândușa Barzaghideanu¹, Raoul Ciprian Burculet², Albert-Andrei Jighirgiu³, Marius Cocu⁴, Corina Ciupilan⁵, Laurian Francu^{6*}, Oana Cristina Cretu⁷, Adina Ilie³, Monica Mihaela Scutariu¹

¹“Gr. T. Popa” U.M.Ph. - Iași, Romania, Faculty of Dentistry, Department of Oral Diagnosis, 700115 Iasi, Romania; Phd student

²“doctor privat practice, Iasi, Romania

³“Faculty of Medicine and Pharmacy, Doctoral School of Biomedical Sciences, “Dunarea de Jos” University of Galati, 47 Domneasca Street 800008 Galati Romania, Phd student

⁴“Psychiatrist, “Anton Cincu” Psychiatric Hospital, Tecuci, Romania, Phd student

⁵“Gr. T. Popa” U.M.Ph. - Iași, Romania, Faculty of Medicine, Department of Morpho Functional Science, 700115 Iasi, Romania;

⁶“Gr. T. Popa” U.M.Ph. - Iași, Romania, Faculty of Medicine, Department of Morphological Science I; 700115 Iasi, Romania.

⁷“Md.Ph.D.Socola Institute, Iasi, Romania

*Corresponding author: *e-mail*: Laurian Francu laurian.francu@umfiiasi.ro

ABSTRACT

Cervical spine impairment is increasingly recognized as a condition with effects that extend beyond the local musculoskeletal level. Current evidence suggests that dysfunctions in the cervical region can influence systemic functional balance, particularly through their connections with craniofacial dynamics and psychological well-being. This narrative review synthesizes current findings on these interconnected pathways, emphasizing mechanisms such as proprioceptive imbalance, autonomic dysregulation, and central sensitization. A better understanding of these links supports the need for integrated assessment strategies and personalized rehabilitation approaches that address cervical, craniofacial, and psychological dimensions simultaneously.

Keywords: cervical spine impairment; systemic functional disturbance; craniofacial pathways; stomatognathic system; proprioceptive dysfunction; psychosocial pathways; central sensitization; integrated rehabilitation.

1.INTRODUCTION

Cervical spine disorders are increasingly understood as conditions whose clinical expression extends beyond local musculoskeletal impairment, influencing multiple functional systems throughout the body. The cervical region plays a central role in postural control, proprioceptive regulation, and sensorimotor integration, making it a key contributor to global functional balance [1,2]. Alterations in cervical biomechanics—such as those produced by disc herniation, segmental instability, or chronic muscle dysfunction—

can propagate downward along interconnected neuromuscular chains, influencing craniofacial dynamics and mandibular function through shared muscular and fascial pathways [3–5].

The stomatognathic system, highly dependent on coordinated cervical input for mandibular positioning and orofacial motor control, may therefore exhibit secondary disturbances in the presence of cervical pathology. These disturbances can manifest as altered occlusal loading, masticatory inefficiency, temporomandibular disorders, or orofacial

pain syndromes, all of which may be amplified by impaired sensorimotor feedback originating from the cervical region [6–8].

In parallel, chronic symptoms associated with cervical dysfunction—such as pain, functional limitation, and reduced proprioceptive accuracy—have been linked to psychological consequences including anxiety, hypervigilance, sleep disturbances, and decreased quality of life [9–11]. The interplay between biomechanical disturbances and psychological vulnerability supports a biopsychosocial interpretation of cervical pathology, where neural sensitization, autonomic dysregulation, and behavioral adaptations contribute to a self-perpetuating cycle of discomfort and dysfunction [12–14]. Given these multidirectional relationships, an integrated understanding of cervical, craniofacial, and psychosocial mechanisms is essential for accurate diagnosis and effective rehabilitation.

This review aims to synthesize current evidence regarding the pathways that link cervical impairment to systemic functional disturbances, with emphasis on craniofacial and psychological outcomes.

2.LITERATURE REVIEW

A growing body of research has examined the multifaceted consequences of cervical spine impairment, highlighting its potential to influence craniofacial function and psychological health through interconnected biomechanical, neurosensory, and behavioral pathways. To contextualize these findings and provide a coherent framework for understanding the systemic implications of cervical dysfunction, the following literature review synthesizes current evidence across key conceptual domains.

We begin by outlining the biomechanical and neurophysiological principles that underlie cervical spine function, followed by an examination of its functional connections with craniofacial systems. Subsequently, we explore the psychosocial dimensions

associated with cervical disorders and integrate these perspectives into a unified model describing cross-system interactions. Finally, we discuss the clinical implications that emerge from this integrative view, emphasizing their relevance for modern rehabilitation strategies.

1. *Cervical Biomechanics and Neurophysiology*

The cervical spine is a key structural and neurophysiological hub responsible for postural control, proprioceptive integration, and coordinated motor function. Its anatomical configuration—featuring high-mobility vertebral segments, dense proprioceptive musculature, and complex ligamentous support—allows for fine-tuned regulation of head position and upper-body dynamics [15,16]. Even minor alterations in cervical joint mechanics or muscle tone can disrupt the quality of afferent sensory input reaching the central nervous system, with downstream effects on balance, head orientation, and spatial perception [17]. Pathological conditions such as cervical disc herniation, segmental hypomobility or hypermobility, and chronic myofascial overload interfere with the synergistic interaction among passive, active, and neural stabilizers. These perturbations contribute to aberrant mechanotransduction, inconsistent afferent signaling from muscle spindles, and compensatory recruitment of superficial musculature, ultimately generating proprioceptive imbalance [18,19]. Such disturbances affect not only cervical motor control but also craniofacial coordination, reflecting the interdependence between cervical mobility and mandibular function [20].

On a neurophysiological level, chronic cervical dysfunction is associated with central sensitization mechanisms, including amplified nociceptive transmission, altered cortical representation of cervical inputs, and diminished efficacy of descending inhibitory pathways [21,22]. These processes facilitate the persistence of pain, reduce motor precision, and predispose patients to symptom propagation across interconnected systems, including craniofacial and autonomic domains [23].

Understanding these biomechanical and neurophysiological mechanisms provides the foundation for interpreting how cervical impairment can evolve into multisystem functional disturbance and guides the development of targeted rehabilitation strategies.

2. Cervicocranial Functional Connections

The functional relationship between the cervical spine and craniofacial structures is supported by a dense network of biomechanical, neuromuscular, and neurophysiological interactions. The upper cervical segments (C0–C3) share direct anatomical continuity with the craniofacial region through muscular and fascial chains, including the suboccipital group, suprahyoid and infrahyoid complexes, and deep cervical flexors, which collectively influence mandibular positioning, tongue posture, and orofacial motor control [24,25]. Dysfunctions affecting these structures—such as muscle hyperactivity, restricted cervical mobility, or altered joint mechanics—may therefore contribute to secondary disturbances in craniofacial coordination and temporomandibular function [26].

Neurophysiologically, the trigeminocervical nucleus serves as a major convergence point for afferent fibers from both the upper cervical roots and the trigeminal system. This shared processing center explains the frequent co-occurrence of cervical pain with orofacial symptoms, including jaw discomfort, facial pain, and temporomandibular disorders [27,28]. Altered proprioceptive input from cervical musculature can disrupt mandibular movement accuracy, chewing efficiency, and occlusal stability, emphasizing the importance of cervical sensory integrity in maintaining normal orofacial function [29].

Moreover, cervical dysfunction may impair postural control mechanisms, leading to compensatory head positioning that modifies occlusal contacts and mandibular biomechanics over time [30]. Such adaptations can perpetuate a cycle of dysfunction, wherein cervical and craniofacial systems mutually influence each other's symptom expression.

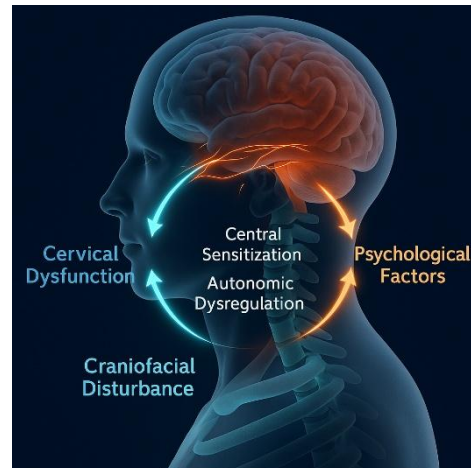


Fig.1- Multisystem Interactions Linking Cervical Dysfunction, Craniofacial Disturbance, and Psychological Factors

Together, these findings highlight the bidirectional nature of cervicocranial interactions and underscore the need for integrated evaluation approaches when assessing patients with combined cervical and orofacial complaints [31].

3. Psychosocial Impact of Cervical Disorders

Cervical spine disorders are increasingly recognized as conditions with significant psychological and behavioral repercussions. Chronic cervical pain and postural discomfort can alter emotional regulation, reduce coping capacity, and contribute to elevated levels of anxiety and stress, particularly when symptoms persist despite standard treatment approaches [32,33]. The continuous nociceptive input associated with cervical dysfunction may activate limbic circuits involved in threat perception, thereby reinforcing hypervigilance and pain-related fear behaviors [34].

Pain catastrophizing—characterized by persistent negative appraisal of symptoms—has been identified as a major mediator of disability in patients with cervical impairment, amplifying perceived pain intensity and limiting functional engagement [35]. Sleep disturbances are also common, driven by nocturnal discomfort, autonomic dysregulation, and increased muscle tension, ultimately contributing to daytime fatigue and reduced cognitive performance [36]. These factors can negatively affect social participation, work capacity, and overall

quality of life, generating a cumulative psychosocial burden [37].

Furthermore, chronic cervical dysfunction is associated with a higher prevalence of depressive symptoms, likely facilitated by long-term pain, reduced mobility, and diminished self-efficacy in managing daily activities [38]. Emotional stress, in turn, may exacerbate cervical muscle hyperactivity and promote maladaptive behavioral responses, creating a bidirectional cycle between psychological distress and musculoskeletal impairment [39].

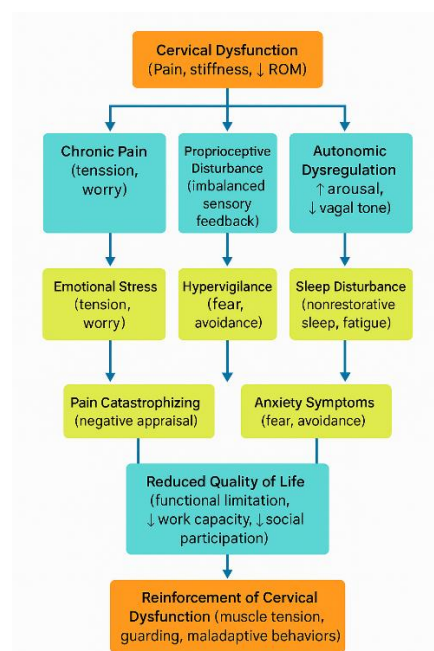


Fig.2-Psychosocial Mechanisms Linking Cervical Dysfunction to Emotional Distress, Sleep Disruption, and Reduced Quality of Life

4. Integrated Cervical–Craniofacial–Psychological Pathways

The interaction between cervical dysfunction, craniofacial disturbances, and psychological factors reflects a complex network of multidirectional pathways rather than isolated cause-effect relationships. Biomechanical alterations at the cervical level influence both mandibular mechanics and trigeminal sensory processing, generating orofacial symptoms that may intensify emotional stress and pain perception [41,42]. Changes in cervical proprioception, impaired head–neck

alignment, and aberrant muscle recruitment strategies create a state of sensorimotor incongruence that can distort the integration of craniofacial inputs, further sensitizing the trigeminocervical system [43].

In parallel, psychological distress, including anxiety, catastrophizing, and hypervigilance—can heighten muscular tension within the cervical and craniofacial regions, reinforcing maladaptive postures and dysfunctional motor patterns. Elevated sympathetic arousal and reduced vagal tone alter baseline neuromuscular excitability, amplifying nociceptive transmission and lowering the threshold for pain-related activation across interconnected regions [44]. These psychophysiological responses may also disrupt motor planning and proprioceptive calibration, promoting compensatory behaviors such as forward-head posture, limited mandibular excursion, and increased reliance on superficial musculature [45].

Over time, the reciprocal reinforcement among biomechanical dysfunction, altered sensory processing, and emotional reactivity contributes to a self-perpetuating cycle in which cervical, craniofacial, and psychological impairments mutually exacerbate one another. This integrated perspective underscores the importance of evaluating patients not solely through the lens of musculoskeletal findings but within a broader biopsychosocial framework capable of explaining symptom persistence and variability in clinical outcomes [46].

Neurophysiologically, the trigeminocervical complex plays a central role in integrating nociceptive input from both the cervical spine and the craniofacial region. Dysregulated afferent signaling at this convergence point facilitates central sensitization and amplifies symptom spread across systems, contributing to chronic pain states that affect both cervical and orofacial domains [44,45]. Autonomic imbalance—characterized by reduced parasympathetic tone and elevated sympathetic drive—further modulates this interaction by altering muscle tone, sleep quality, and stress responsiveness [46].

Behaviorally, patients often adopt compensatory strategies to manage

discomfort, including forward-head posture, limited mandibular excursion, and avoidance of certain functional movements. These adaptations may temporarily reduce symptoms but ultimately perpetuate biomechanical overload and sensory dysregulation, creating a self-sustaining loop of dysfunction across cervical, craniofacial, and psychological dimensions [47,48].

Over time, these compensations alter the distribution of mechanical forces within both the cervical and craniofacial regions, increasing reliance on superficial musculature and reducing the efficiency of deep stabilizers. This redistribution contributes to fatigue, increased muscle tone, and reduced postural stability, all of which further degrade proprioceptive accuracy and motor coordination [49].

Moreover, protective behavioral patterns often interact with psychological factors such as fear-avoidance beliefs and heightened vigilance toward bodily sensations. Patients may restrict jaw opening, minimize neck rotation, or avoid activities perceived as risky, inadvertently reinforcing maladaptive neural circuits associated with pain expectancy and threat perception [50].

These behaviors promote cortical reorganization that favors pain-related pathways, lowering the threshold for symptom activation and fostering persistent central sensitization [51].

Consequently, what begins as an attempt to reduce discomfort evolves into a multidimensional cycle in which motor behavior, sensory integration, and psychological reactivity continuously influence one another.

This dynamic reinforces the chronicity of symptoms and contributes to the variability and complexity of clinical presentations seen in patients with coexisting cervical and craniofacial disorders.

5. Clinical and Rehabilitation Implications

The multidimensional interactions among cervical, craniofacial, and psychological factors have significant implications for clinical assessment and rehabilitation.

Traditional approaches that address cervical or orofacial symptoms in isolation often fail to capture the complexity of multisystem dysfunction and may therefore yield suboptimal outcomes [53]. An integrated assessment should include evaluation of cervical mobility and muscle function, temporomandibular joint mechanics, trigeminal sensitivity, postural alignment, and psychosocial indicators such as anxiety, catastrophizing, and sleep quality [54,55]. This expanded diagnostic framework allows clinicians to identify the dominant drivers of dysfunction and the reinforcing loops that maintain symptom chronicity.

Rehabilitation strategies must similarly adopt a multidomain perspective. Evidence supports the use of combined interventions, including cervical manual therapy, deep cervical flexor training, sensorimotor re-education, and targeted temporomandibular rehabilitation to restore biomechanical efficiency across interconnected regions [56,57].

These approaches may be complemented by modalities aimed at modulating central sensitization—such as graded exposure, breathing regulation, patient education, and cognitive-behavioral strategies that reduce fear-avoidance beliefs and enhance self-efficacy [58].

Interventions targeting autonomic regulation, such as diaphragmatic breathing, biofeedback, and sleep optimization, may further mitigate sympathetic overactivation and improve pain modulation pathways [59].

Because behavioral adaptations play a key role in perpetuating dysfunction, rehabilitation should emphasize correction of postural habits, optimization of mandibular movement patterns, and gradual reintroduction of avoided activities to interrupt maladaptive motor and cognitive cycles [60].

Ultimately, a coordinated, interdisciplinary approach—integrating musculoskeletal therapy, dental/orofacial management, and psychological support—is essential for addressing the complex symptomatology associated with combined cervical and craniofacial disorders. Such models are increasingly recognized as critical for

improving long-term outcomes and reducing the recurrence of chronic pain patterns [61].

3.FUTURE PERSPECTIVES:

Despite the growing interest in the multidimensional relationship between cervical dysfunction, craniofacial disturbances, and psychological factors, the current body of evidence remains limited by several methodological constraints. Much of the available research is cross-sectional, which restricts the ability to establish temporal or causal relationships among these interconnected domains. Sample heterogeneity across studies—regarding age, symptom duration, comorbidities, and diagnostic criteria—also complicates the comparison and generalization of findings.

The assessment methods used in existing literature often rely on isolated biomechanical or self-reported measures, which may not fully capture the complexity of multisystem interactions. Few studies incorporate comprehensive evaluations that include cervical motor control, temporomandibular function, trigeminal sensitivity, autonomic regulation, and psychosocial dimensions simultaneously. This fragmented approach risks overlooking subtle but clinically relevant associations.

Additionally, there is a scarcity of high-quality randomized trials testing integrated rehabilitation strategies. Most interventions target only one component of the dysfunction—either cervical biomechanics, orofacial symptoms, or psychological factors—making it difficult to determine the relative contribution and optimal sequencing of multimodal treatments.

Technological limitations further constrain the field. Although advanced tools such as neuroimaging, motion analysis, and quantitative sensory testing are increasingly available, they are not yet routinely applied in combined cervical–craniofacial research

contexts. As a result, the underlying mechanisms linking these domains remain incompletely understood.

Finally, many studies include small sample sizes and lack long-term follow-up, reducing their ability to detect clinically meaningful changes or the persistence of treatment effects over time. These limitations highlight the need for larger, methodologically rigorous, and truly interdisciplinary research designs.

Future research should aim to refine our understanding of the multidirectional interactions linking cervical, craniofacial, and psychological domains. Although current evidence supports the interdependence of these systems, much remains unknown regarding the precise temporal sequence of symptom development and the key mechanisms that drive the transition from acute to chronic dysfunction. Longitudinal studies and mechanistic investigations are needed to clarify how alterations in cervical proprioception, trigeminal processing, autonomic function, and emotional regulation collectively contribute to multisystem impairment.

Emerging technologies such as neuroimaging, quantitative sensory testing, high-resolution motion analysis, and wearable biosensors offer new opportunities to capture real-time interactions across these domains. Integrating these tools into clinical research may facilitate the identification of distinct symptom phenotypes and support the development of predictive models for personalized rehabilitation.

There is also a growing need for well-designed clinical trials that evaluate interdisciplinary treatment strategies. Approaches combining cervical-focused interventions, temporomandibular rehabilitation, autonomic regulation, and psychologically informed therapies may produce superior outcomes compared to isolated treatment modalities, but

robust comparative evidence is still limited. Finally, future work should explore how individual factors—such as stress reactivity, coping style, sleep patterns, and baseline neuromuscular control—influence treatment responsiveness. Identifying modifiable

4.CONCLUSIONS

- ✓ Cervical dysfunction, craniofacial disturbances, and psychological factors form a tightly interconnected system in which impairments in one domain can propagate and intensify dysfunction in the others. The evidence reviewed in this paper highlights that biomechanical alterations in the cervical spine influence trigeminal processing, mandibular mechanics, and orofacial pain, while psychological factors such as anxiety, catastrophizing, and hypervigilance modulate neuromuscular tone, pain perception, and autonomic balance. These multidirectional interactions contribute to cycles of symptom amplification that can sustain or worsen chronic conditions over time.
- ✓ Understanding these relationships requires a conceptual shift away from reductionist, single-system interpretations toward a more integrative biopsychosocial perspective. Such an approach acknowledges the dynamic interplay

predictors of recovery will support the development of precision-based rehabilitation frameworks capable of interrupting the self-reinforcing cycle that characterizes cervical–craniofacial–psychological dysfunction.

- between musculoskeletal, neurosensory, and emotional processes and provides a more accurate framework for diagnosis, prognosis, and treatment planning.
- ✓ Clinically, this synthesis underscores the importance of interdisciplinary assessment and multimodal rehabilitation strategies that address cervical biomechanics, temporomandibular function, central sensitization, autonomic regulation, and psychological contributors simultaneously. Recognizing and interrupting the self-reinforcing loops that characterize these disorders may improve patient outcomes, reduce chronicity, and enhance quality of life.
- ✓ The cumulative evidence suggests that future progress will depend on collaborative research that bridges musculoskeletal science, neuroscience, dentistry, and psychology. Such integration will be essential for developing personalized, mechanism-based interventions capable of addressing the full complexity of cervical–craniofacial–psychological dysfunction.

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