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Biomechanical Impact of Text Neck Syndrome on Cervical Spine and Upper-Quarter Musculoskeletal System

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Abstract

Text Neck Syndrome (TNS) has emerged as a modern musculoskeletal disorder associated with prolonged use of handheld digital devices, resulting in sustained cervical flexion and altered spinal biomechanics. This article explores the biomechanical consequences of TNS on the cervical spine and upper quarter musculoskeletal system, including muscular imbalance, altered load distribution, ligamentous strain, and degenerative changes. Increased cervical flexion significantly elevates compressive forces on intervertebral discs and facet joints, disrupting normal spinal alignment and leading to functional impairments. Secondary effects extend to the thoracic spine, shoulder girdle, and upper limb musculature, contributing to pain, reduced mobility, and postural dysfunction. The review integrates recent evidence on kinematics, muscle activation patterns, and neurophysiological adaptations associated with prolonged device use. Early identification and biomechanical correction strategies are essential to mitigate long-term complications. This article emphasizes the need for ergonomic awareness, targeted rehabilitation, and preventive interventions to address the growing burden of TNS in the digital era.

Keywords: Text neck syndrome, cervical spine biomechanics, forward head posture, musculoskeletal disorders, upper quarter dysfunction

INTRODUCTION

Text Neck Syndrome is increasingly recognized as a modern repetitive strain disorder arising from prolonged use of smartphones, tablets, and other digital devices, which promote sustained forward head posture and place abnormal mechanical stress on the cervical spine. This condition is characterized by a progressive alteration in normal spinal alignment, where the head shifts anteriorly relative to the shoulders, thereby increasing the load borne by cervical vertebrae, intervertebral discs, ligaments, and surrounding musculature. Under normal conditions, the human head weighs approximately 4–5 kg in a neutral position. however, as the neck flexes forward, the effective load increases significantly, reaching up to 27 kg at 60 degrees of flexion, which places excessive strain on the cervical spine [1–5]. This abnormal load distribution contributes to muscle fatigue, ligamentous overstretching, and early degenerative changes within spinal structures, as demonstrated in biomechanical models and imaging-based studies. Figure 1 conceptually illustrates this progressive increase in load with varying degrees of neck flexion, emphasizing how even slight deviations from neutral posture can significantly elevate compressive forces on cervical tissues. The widespread use of handheld devices has transformed daily habits, particularly among adolescents and young adults, who spend several hours daily engaged in texting, gaming, and social media, thereby increasing the risk of developing chronic musculoskeletal disorders. In occupational settings, especially among office workers and students, prolonged screen exposure without

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ergonomic support further exacerbates postural imbalances, leading to cumulative microtrauma and functional impairment**.** Over time, these repetitive stresses may result in symptoms, such as neck pain, stiffness, reduced range of motion, headaches, and even radiating pain, due to nerve compression or irritation. Moreover, altered cervical curvature, including loss of lordosis, has been observed in individuals with prolonged forward head posture, indicating structural adaptations that may predispose to long-term spinal dysfunction [6–8]. The pathophysiology of Text Neck Syndrome involves not only mechanical overload but also neuromuscular imbalance, where anterior cervical muscles become shortened and posterior muscles become weakened, disrupting normal postural stability**.** This imbalance further perpetuates poor posture, creating a cycle of strain and discomfort that is difficult to reverse without targeted intervention. Additionally, research suggests that prolonged device use is associated with decreased proprioceptive awareness and impaired postural control, which may increase the risk of further musculoskeletal complications. The condition is particularly concerning in younger populations, as early exposure to poor postural habits may lead to long-term spinal health issues and reduced quality of life. Preventive strategies, including ergonomic education, regular breaks, posture correction exercises, and strengthening of cervical and upper back muscles, have been shown to mitigate the adverse effects of prolonged device use. Furthermore, integrating digital health technologies and wearable posture monitors may provide real-time feedback and promote healthier behavioral patterns, thereby reducing the burden of Text Neck Syndrome [9–12].

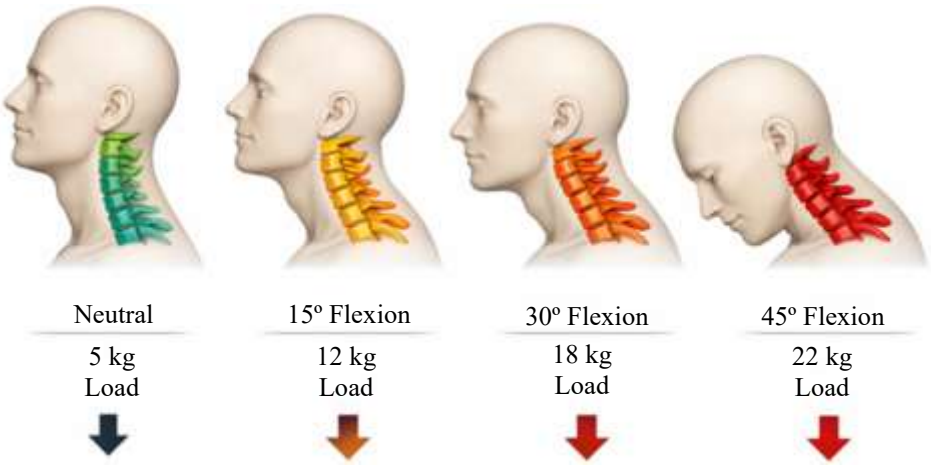


Figure 1. Load distribution across the cervical spine at varying angles of neck flexion
Biomechanics of Normal Cervical Spine.

The cervical spine is a highly specialized anatomical and biomechanical structure composed of seven vertebrae (C1–C7), intervertebral discs, facet joints, ligaments, and an intricate network of muscles that function synergistically to provide both mobility and stability while supporting the weight of the head and facilitating multidirectional movement [13–15]. These components operate as an integrated system in which the anterior column, consisting primarily of vertebral bodies and intervertebral discs, bears compressive loads, while the posterior elements, including facet joints and ligamentous structures, guide motion and resist excessive movement. In normal biomechanics, load sharing between these anterior and posterior elements is well balanced, allowing efficient transmission of forces during static posture and dynamic activities such as flexion, extension, and rotation. A key feature of this biomechanical efficiency is the presence of physiological cervical lordosis, a natural inward curvature that plays a crucial role in maintaining sagittal alignment, optimizing load distribution, and reducing energy expenditure by minimizing muscular effort required to support the head. As illustrated in Figure 2, this lordotic curvature allows mechanical loads to be evenly dispersed across intervertebral discs, facet joints, and supporting musculature, thereby preventing localized stress concentrations that could otherwise lead to tissue fatigue and degeneration [16–20]. The curvature also acts as a shock-absorbing mechanism, attenuating forces transmitted from the skull to the thoracic spine during daily activities and sudden movements, thus preserving structural integrity. Additionally, cervical lordosis ensures that

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the line of gravity passes through the vertebral bodies in an optimal manner, reducing shear forces and enhancing biomechanical stability. The intervertebral discs contribute to this process by distributing compressive loads through their viscoelastic properties, while facet joints provide controlled articulation and limit excessive motion, thereby preventing instability. Ligaments, including the anterior and posterior longitudinal ligaments, ligamentum flavum, and interspinous ligaments, further enhance stability by restricting abnormal movements and maintaining alignment under varying loads. Muscles surrounding the cervical spine, particularly the deep cervical flexors and extensors, play an essential role in dynamic stabilization, posture maintenance, and load sharing, ensuring coordinated movement and preventing excessive strain on passive structures. When this finely tuned biomechanical balance is maintained, the cervical spine operates efficiently with minimal stress on individual components, thereby reducing the risk of injury and degeneration [21–24]. However, disruption of this equilibrium, whether due to poor posture, trauma, or degenerative changes, leads to altered load distribution and compensatory mechanisms in surrounding tissues, often resulting in increased stress on specific segments of the spine. For instance, loss of cervical lordosis has been shown to shift mechanical loads from mid-cervical regions to upper and lower segments, significantly increasing stress and strain on intervertebral discs and facet joints, which may accelerate degenerative processes. Similarly, changes in spinal curvature can alter muscle activation patterns, leading to fatigue and imbalance that further exacerbate mechanical inefficiency. External factors, such as improper pillow height or inadequate ergonomic support, can also influence cervical alignment and pressure distribution, highlighting the sensitivity of this region to positional changes. Over time, these biomechanical alterations may contribute to chronic neck pain, reduced range of motion, and functional limitations, underscoring the importance of maintaining normal cervical alignment and biomechanics [25–28].

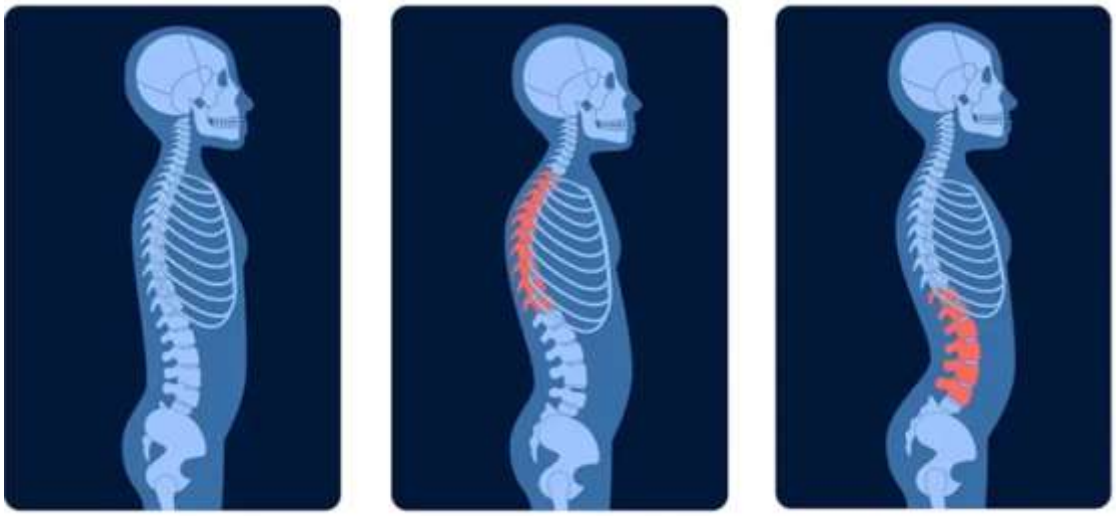


Figure 2. Normal cervical spine alignment with physiological lordosis.

ALTERED BIOMECHANICS IN TEXT NECK SYNDROME

Prolonged cervical flexion significantly alters normal spinal biomechanics by shifting the head's center of gravity anteriorly, thereby increasing the moment arm and necessitating greater muscular effort from cervical extensors to maintain head position against gravity [29, 30]. This anterior displacement, commonly observed in forward head posture, leads to a measurable increase in mechanical demand on the cervical spine, as even small deviations from neutral alignment can substantially amplify the forces acting on vertebral and soft tissue structures. As illustrated in Figure 3, the forward positioning of the head creates a longer lever arm relative to the cervical spine, which increases torque and results in greater compressive and shear forces on intervertebral discs and facet joints. This biomechanical alteration requires continuous activation of posterior cervical muscles, leading to muscular fatigue, overuse, and eventual imbalance between anterior and posterior muscle

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groups. Over time, the sustained increase in muscular demand contributes to inefficient neuromuscular control and reduced endurance of deep cervical stabilizers, which are essential for maintaining proper spinal alignment. In addition to muscular strain, prolonged forward head posture redistributes loads unevenly across cervical vertebrae, particularly increasing stress in mid-cervical segments, such as C2–C3, where elevated cortical bone stress and altered curvature patterns have been observed in biomechanical models. These structural adaptations often include increased upper cervical extension and lower cervical flexion, resulting in a loss of normal lordotic curvature and further exacerbating mechanical inefficiency [31–33]. The increased loading on intervertebral discs accelerates degenerative processes, including annular fiber weakening and potential disc herniation, particularly in individuals exposed to prolonged static postures. Similarly, facet joints experience higher compressive forces due to altered alignment, which may contribute to facet joint arthropathy and chronic neck pain [34–37]. Ligamentous structures, including the anterior and posterior longitudinal ligaments, are subjected to prolonged tensile stress under sustained flexion, leading to gradual elongation and laxity that compromises spinal stability. This ligamentous laxity further increases segmental instability, requiring additional muscular compensation and perpetuating a cycle of mechanical overload and dysfunction. Furthermore, anterior displacement of the head affects proprioceptive input from cervical mechanoreceptors, impairing postural control and coordination, which may increase susceptibility to further injury. The altered biomechanics also influence neural structures, as elongation of the cervical spine can place tension on the spinal cord and nerve roots, potentially leading to neurological symptoms such as pain, tingling, or numbness. In addition, sustained abnormal loading contributes to microtrauma within spinal tissues, which accumulates over time and leads to chronic inflammation and structural degeneration. These cumulative effects are particularly concerning in individuals with prolonged screen exposure, as repetitive stress without adequate recovery prevents tissue healing and accelerates degenerative changes [38–41]. Ultimately, prolonged cervical flexion not only increases the mechanical load on cervical structures through an extended moment arm but also disrupts the intricate balance between stability and mobility, leading to ligament laxity, segmental instability, and early degenerative changes, such as disc herniation and facet joint arthropathy, thereby significantly impacting long-term spinal health and functional capacity [42–45].

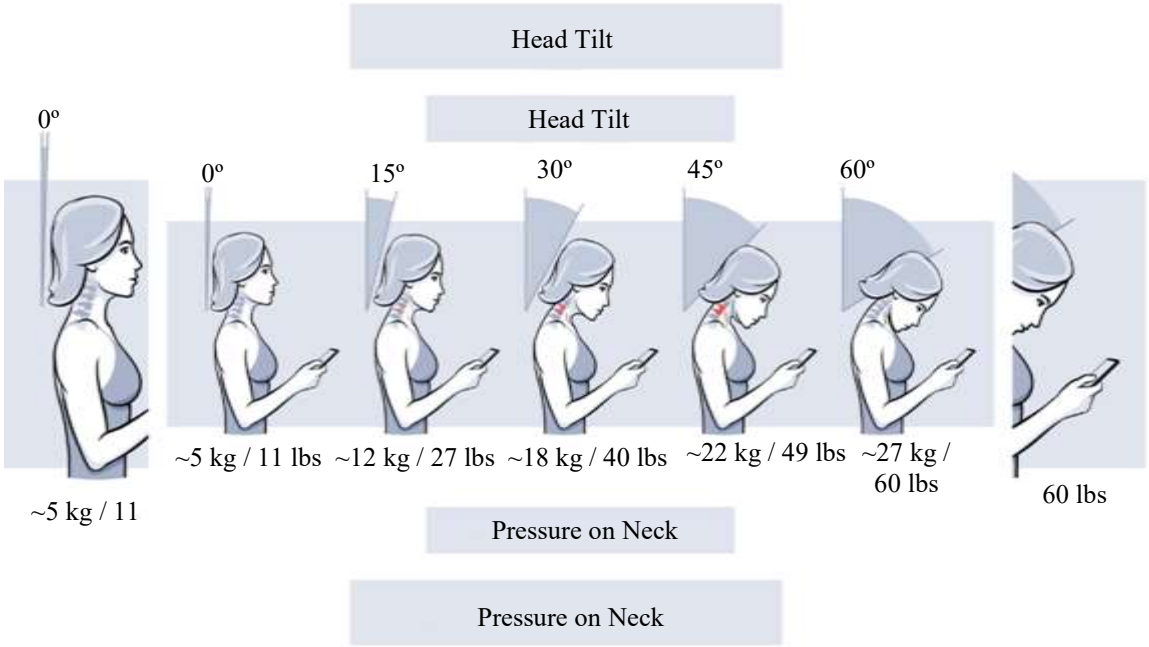


Figure 3. Forward head posture and increased moment arm in text neck syndrome.

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MUSCULAR IMBALANCE AND UPPER QUARTER DYSFUNCTION

Text Neck Syndrome is strongly associated with characteristic patterns of muscle imbalance, primarily involving weakening of the deep cervical flexor muscles and compensatory overactivation of superficial muscles, such as the upper trapezius, levator scapulae, and suboccipital muscles, which together disrupt normal neuromuscular coordination and postural stability [46–48]. The deep neck flexors, including the longus colli and longus capitis, play a crucial role in maintaining cervical alignment and providing segmental stability. however, prolonged forward head posture reduces their activation and endurance, leading to diminished support for the cervical spine. As these stabilizing muscles weaken, superficial muscles, such as the sternocleidomastoid and upper trapezius, become overactive to compensate for the loss of deep muscle function, resulting in increased muscular tension and fatigue. Figure 4 illustrates this imbalance pattern, where posterior cervical muscles exhibit tightness and overactivity, while anterior stabilizing muscles are inhibited and weakened, creating a biomechanical environment that favors poor posture and increased mechanical stress on cervical structures [49].

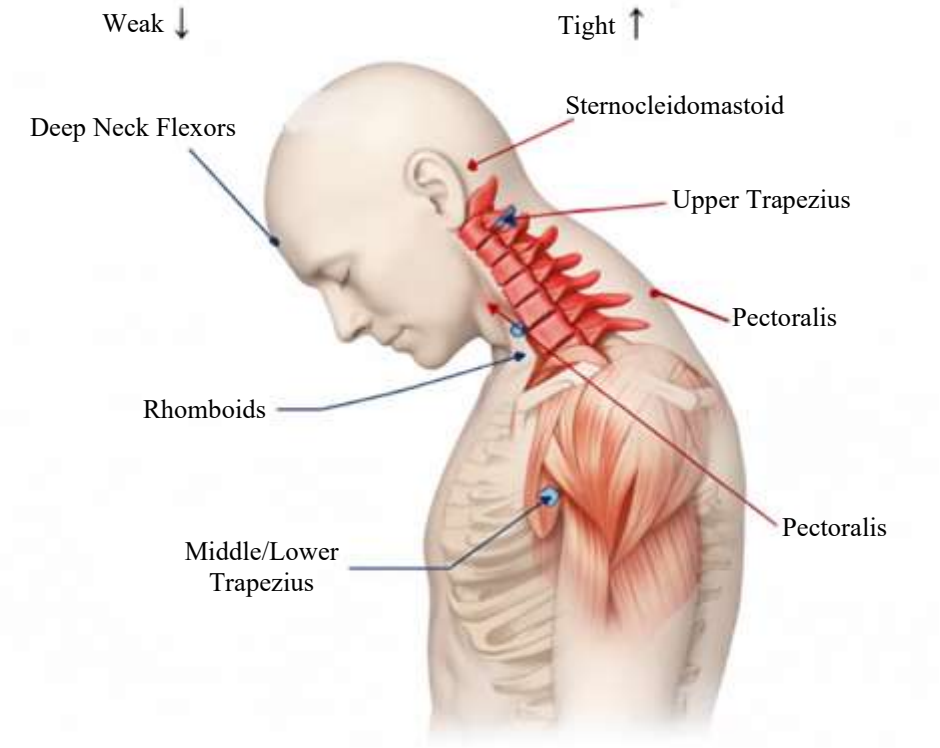


Figure 4. Muscle imbalance patterns in text neck syndrome.

This imbalance is often described as part of the upper crossed syndrome pattern, where tightness in the upper trapezius, levator scapulae, and suboccipital muscles is paired with weakness in deep neck flexors and lower scapular stabilizers, leading to a forward head and rounded shoulder posture. The sustained contraction of posterior cervical muscles not only increases compressive forces on the cervical spine but also contributes to reduced blood flow and accumulation of metabolic waste, which may exacerbate pain and discomfort. Additionally, overactivity of the suboccipital muscles has been linked to tension-type headaches due to their close anatomical relationship with cranial structures and neural pathways [50–52]. These muscular changes are not limited to the cervical region but extend to the shoulder girdle, where altered muscle activation patterns lead to scapular dyskinesis, characterized by abnormal movement and positioning of the scapula during upper limb motion. Weakness of the middle and lower trapezius and rhomboid muscles further contributes to scapular instability, while tightness in the pectoralis minor pulls the shoulders forward, reinforcing a rounded shoulder posture. As a result, the normal scapulohumeral rhythm is disrupted, affecting upper limb biomechanics and potentially

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leading to shoulder impingement, reduced range of motion, and functional limitations. The interplay between cervical and scapular musculature highlights the interconnected nature of the musculoskeletal system, where dysfunction in one region can propagate to adjacent areas, amplifying biomechanical inefficiencies [53–56]. Table 1 summarizes these key muscular alterations by categorizing them into weakened, overactive, and shortened muscle groups, demonstrating how these imbalances collectively contribute to altered biomechanics and postural deviations. Weakened muscles typically include the deep neck flexors, lower trapezius, and rhomboids, which are essential for maintaining upright posture and scapular stability. Overactive and shortened muscles commonly include the upper trapezius, levator scapulae, sternocleidomastoid, and pectoralis minor, all of which contribute to forward head posture and rounded shoulders when excessively activated. These imbalances create a cycle in which poor posture reinforces abnormal muscle activation patterns, further weakening stabilizing muscles and increasing reliance on compensatory mechanisms. Over time, this cycle can lead to chronic musculoskeletal dysfunction, reduced functional capacity, and increased risk of injury, particularly in individuals with prolonged exposure to digital devices and sedentary lifestyles [57–60].

Table 1. Common muscular imbalances in text neck syndrome.

Muscle group	Condition (tight/weak)	Description of imbalance	Functional impact
Upper trapezius	Tight	Overactivation due to sustained neck elevation	Neck stiffness and reduced cervical mobility.
Levator scapulae	Tight	Shortening from prolonged forward head posture	Pain along neck and medial scapular border.
Sternocleidomastoid	Tight	Increased activity to support forward head position	Headache and anterior neck discomfort.
Suboccipital muscles	Tight	Constant contraction to stabilize head in forward position	Tension headaches and reduced craniovertebral mobility.
Pectoralis major and minor	Tight	Adaptive shortening due to rounded shoulder posture	Shoulder protraction and thoracic kyphosis.
Deep cervical flexors	Weak	Inhibited due to reliance on superficial neck muscles	Poor neck stability and forward head posture.
Lower trapezius	Weak	Reduced activation from altered scapular mechanics	Scapular instability and poor posture.
Rhomboids	Weak	Lengthened due to protracted shoulders	Decreased scapular retraction.
Serratus anterior	Weak	Impaired activation affecting scapular positioning	Shoulder dysfunction and winging of scapula.
Cervical extensors (deep)	Weak	Overpowered by superficial muscles	Reduced cervical support and endurance.

IMPACT ON INTERVERTEBRAL DISCS AND FACET JOINTS

Sustained cervical flexion produces significant biomechanical alterations within the spinal column by increasing anterior compressive forces on the intervertebral discs while simultaneously placing tensile stress on posterior ligamentous structures, thereby disrupting normal load-sharing mechanisms and predisposing the spine to degenerative changes. In a flexed posture, the nucleus pulposus is displaced posteriorly, resulting in uneven stress distribution across the annulus fibrosus and increasing the risk of annular fiber strain and eventual disc herniation [61–63]. This anterior shift in load concentration elevates intradiscal pressure, particularly under prolonged or repetitive flexion, which compromises disc hydration and structural integrity over time. As illustrated in Figure 5, disc compression in a flexed cervical posture is accompanied by a redistribution of forces away from posterior elements, leading to reduced facet joint contact in early flexion but increased abnormal loading patterns during combined or prolonged movements. Although facet joints typically guide and stabilize spinal motion, flexion alters their alignment and contact mechanics, potentially reducing their stabilizing role and transferring excessive loads to discs and ligaments. However, in certain dynamic or asymmetrical conditions, facet joints may experience increased localized stress due to altered

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kinematics, contributing to cartilage wear and degenerative joint changes [64]. The posterior ligament complex, including the posterior longitudinal ligament, ligamentum flavum, and interspinous ligaments, undergoes sustained tensile loading during flexion, which can lead to gradual elongation, reduced stiffness, and compromised passive stability. This ligamentous strain reduces the spine's ability to resist excessive motion, thereby increasing the risk of segmental instability and abnormal vertebral translation. Over time, repetitive loading under flexed conditions contributes to cumulative microdamage within disc and ligamentous tissues, which accelerates degenerative processes such as disc desiccation, annular tears, and decreased disc height. The reduction in disc height further alters spinal alignment, increasing stress on adjacent segments and creating a cascade of biomechanical dysfunction. Additionally, flexion-induced changes in facet joint orientation may lead to abnormal shear forces, which have been implicated in the development of facet joint arthropathy and chronic neck pain syndromes. The interplay between increased anterior disc loading and altered posterior element mechanics highlights the complex nature of cervical spine biomechanics under sustained flexion, where both compressive and tensile forces act simultaneously on different structures. Continuous exposure to such altered loading conditions, particularly in individuals with prolonged screen use or poor ergonomic habits, prevents adequate tissue recovery and promotes progressive structural deterioration [65]. Furthermore, the loss of normal load distribution compromises the shock-absorbing capacity of the cervical spine, making it more susceptible to injury even under relatively low mechanical stress. These biomechanical changes also influence neuromuscular control, as altered proprioceptive input from strained ligaments and degenerated discs impairs coordination and postural stability. As degeneration progresses, the combined effects of disc compression, ligament laxity, and facet joint stress contribute to a reduction in overall spinal stability, increasing the likelihood of chronic pain, stiffness, and functional limitations. Ultimately, sustained cervical flexion results in a complex redistribution of forces characterized by increased anterior disc compression, posterior ligament tension, and altered facet joint loading, all of which accelerate degenerative changes and compromise the structural and functional integrity of the cervical spine [66].

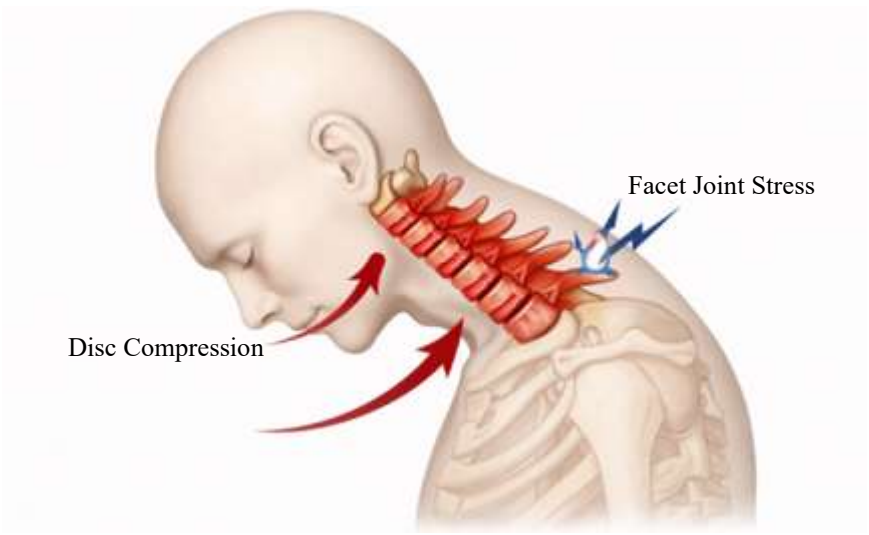


Figure 5. Disc compression and facet joint stress in flexed cervical posture.

NEUROLOGICAL AND PROPRIOCEPTIVE CHANGES

Chronic mechanical stress associated with Text Neck Syndrome has significant implications for neural structures, as sustained cervical compression and altered spinal alignment can contribute to nerve root irritation, leading to symptoms such as tingling, numbness, and radiating pain along the upper extremities. Prolonged forward head posture increases compressive forces on cervical vertebrae and surrounding tissues, which may narrow intervertebral foramina and mechanically irritate spinal nerves, thereby producing neuropathic symptoms and functional deficits. In addition to direct neural compression, chronic loading can induce inflammatory responses in surrounding tissues, further

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sensitizing nerve endings and amplifying pain perception [67]. Figure 6 illustrates how sustained compression and altered biomechanics influence nerve pathways, demonstrating the relationship between mechanical stress and neurological symptoms observed in individuals with prolonged device use. Beyond pain and sensory disturbances, cervical spine dysfunction also affects proprioception, which is a critical component of neuromuscular control and spatial orientation. The cervical region contains a high density of mechanoreceptors, including muscle spindles and joint receptors, which provide continuous feedback to the central nervous system regarding head position and movement. Sustained abnormal posture disrupts this sensory input by altering muscle length, joint alignment, and receptor sensitivity, leading to impaired joint position sense and increased joint position error. As a result, individuals with Text Neck Syndrome often exhibit deficits in proprioception, which compromise their ability to accurately perceive head and neck position in space and maintain postural stability. These proprioceptive impairments have broader implications for balance and coordination, as cervical sensory input interacts closely with visual and vestibular systems to regulate equilibrium and movement control. Disruption of this integrated system can lead to sensorimotor dysfunction, characterized by delayed reflex responses, poor coordination, and increased risk of falls or movement-related injuries. Furthermore, altered proprioceptive feedback from the cervical spine may impair cervico-ocular and cervicocollic reflexes, which are essential for stabilizing gaze and coordinating head movements during dynamic activities. This can result in symptoms such as dizziness, visual disturbances, and difficulty maintaining balance, particularly during rapid head movements or changes in posture [68]. The relationship between chronic neck pain and proprioceptive dysfunction is well established, with studies demonstrating that individuals with cervical disorders exhibit significantly reduced proprioceptive accuracy compared to healthy controls. These deficits are believed to arise from both peripheral and central mechanisms, including altered receptor function and changes in central sensory processing pathways. Additionally, prolonged mechanical stress may lead to adaptive changes in neural pathways, resulting in maladaptive motor patterns and further deterioration of postural control. Over time, the combination of nerve compression, inflammation, and impaired proprioception creates a cycle of dysfunction in which altered sensory input leads to poor motor output, further exacerbating mechanical stress on the cervical spine. This cycle contributes to the persistence and progression of symptoms, including chronic pain, stiffness, and functional limitations, particularly in individuals with prolonged exposure to digital devices. Ultimately, chronic mechanical stress in Text Neck Syndrome not only affects musculoskeletal structures but also disrupts neural and sensory systems, leading to neurological symptoms and impaired neuromuscular coordination, thereby significantly impacting overall functional capacity and quality of life [69].

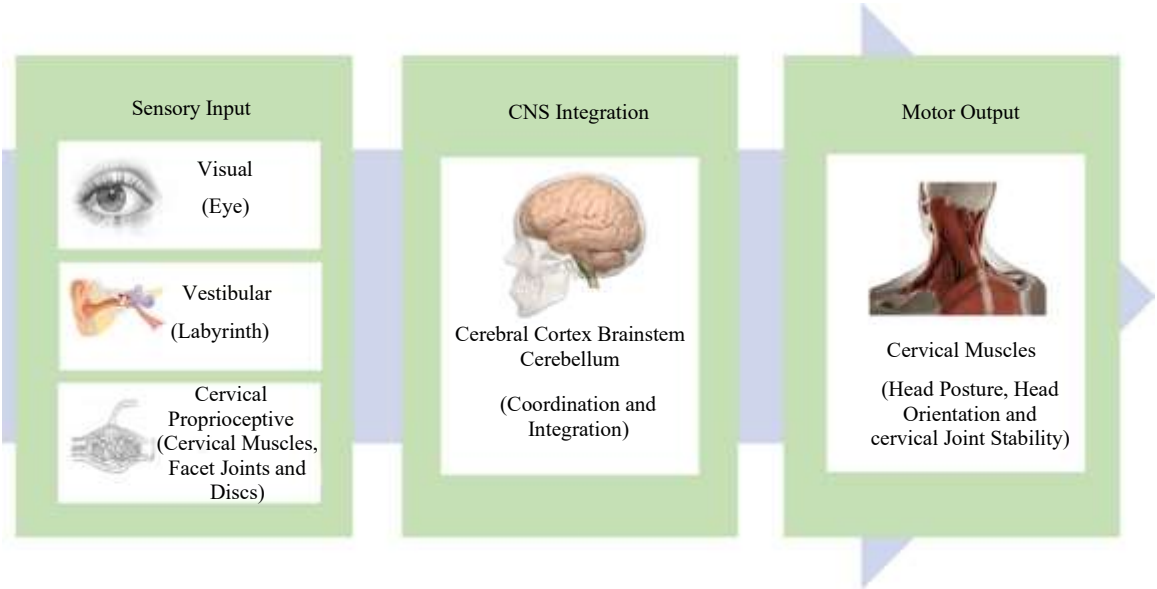


Figure 6. Neurological involvement and altered proprioception in text neck syndrome.

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INFLUENCE ON THORACIC SPINE AND SHOULDER COMPLEX

The effects of Text Neck Syndrome extend beyond the cervical spine, influencing the thoracic region and shoulder girdle through interconnected biomechanical and neuromuscular pathways, thereby demonstrating its impact as a whole-body musculoskeletal disorder rather than an isolated cervical issue. Prolonged forward head posture is frequently accompanied by increased thoracic kyphosis, which alters the normal sagittal alignment of the spine and shifts the center of mass anteriorly, thereby increasing mechanical demand on postural muscles and reducing overall biomechanical efficiency This increase in thoracic flexion contributes to compensatory changes in the cervical spine and shoulder complex, creating a chain reaction of postural adaptations that affect multiple regions simultaneously [70]. As illustrated in Figure 7, the kinetic chain involvement from the cervical spine to the thoracic and shoulder regions highlights how alterations in one segment can influence adjacent structures, emphasizing the concept of regional interdependence in musculoskeletal function. Increased thoracic kyphosis has been shown to significantly affect scapular positioning, often resulting in protraction, downward rotation, and anterior tilting of the scapula, which collectively contribute to scapular dyskinesis. These changes in scapular orientation disrupt normal scapulothoracic rhythm, which is essential for efficient shoulder movement and load distribution during upper limb activities. The scapula serves as a stable base for humeral motion, and any alteration in its position or movement pattern can significantly impair shoulder joint biomechanics and functional performance. Consequently, individuals with Text Neck Syndrome often experience reduced shoulder range of motion, decreased strength, and increased susceptibility to overuse injuries such as impingement syndromes. Furthermore, altered scapular kinematics have been linked to abnormal clavicular and shoulder joint movements, which may increase strain on surrounding soft tissues and contribute to pain and dysfunction. The presence of scapular dyskinesis is strongly associated with chronic neck pain, suggesting a bidirectional relationship in which cervical dysfunction influences scapular mechanics and vice versa. In addition, thoracic spine stiffness resulting from prolonged flexed posture limits extension mobility, which is necessary for optimal shoulder elevation and overhead activities, thereby further compromising upper limb function. The combined effect of increased thoracic kyphosis and scapular malalignment leads to inefficient force transmission across the kinetic chain, requiring compensatory muscle activation patterns that increase energy expenditure and fatigue. Over time, these compensations contribute to chronic musculoskeletal strain, reduced functional capacity, and an increased risk of injury in both the cervical and shoulder regions. Additionally, muscle imbalances associated with Text Neck Syndrome, such as tight pectoral muscles and weak scapular stabilizers, further exacerbate thoracic and scapular dysfunction, reinforcing poor posture and perpetuating a cycle of biomechanical inefficiency. The concept of the kinetic chain emphasizes that the body functions as an integrated system, where impairments in one region can lead to compensatory changes and dysfunction in others, highlighting the importance of a holistic approach to assessment and management. Ultimately, the widespread effects of Text Neck Syndrome across the cervical, thoracic, and shoulder regions underscore the need to consider it as a global biomechanical disorder, as the interconnected nature of these structures plays a critical role in maintaining posture, movement efficiency, and overall musculoskeletal health [71].

FUNCTIONAL AND CLINICAL CONSEQUENCES

Patients with Text Neck Syndrome commonly present with a wide spectrum of clinical symptoms that reflect both musculoskeletal and neurological involvement, with neck pain being the most frequently reported complaint due to sustained mechanical loading and muscle fatigue associated with prolonged forward head posture. This neck pain is often accompanied by reduced cervical range of motion, as repetitive strain and altered joint mechanics limit mobility and contribute to stiffness in cervical structure [52–60]. Individuals frequently report discomfort that may extend beyond the neck into the shoulders and upper limbs, reflecting the interconnected nature of cervical and upper extremity biomechanics and the involvement of neural pathways Headaches, particularly cervicogenic headaches, are another common symptom, arising from sustained tension in cervical muscles and irritation of upper cervical nerves In many cases, these headaches are associated with prolonged static postures and increased muscle activity in the suboccipital region, which contributes to referred pain patterns. Figure 6 conceptually explains how neurological involvement occurs in Text Neck Syndrome, demonstrating

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how sustained compression and altered alignment affect nerve pathways and sensory feedback mechanisms. Neurological symptoms, such as tingling, numbness, and radiating pain into the upper extremities, may develop due to nerve root compression or irritation caused by narrowed intervertebral spaces and degenerative changes. These symptoms are indicative of cervical radiculopathy, a condition that may arise as a long-term consequence of persistent abnormal loading on the cervical spine. In addition to sensory disturbances, proprioceptive deficits are increasingly recognized in individuals with Text Neck Syndrome, as altered cervical alignment affects mechanoreceptor function and disrupts joint position sense. This impairment in proprioception can compromise postural control and balance, leading to reduced coordination and increased risk of further musculoskeletal injury. The cumulative effect of these symptoms significantly impacts daily activities, as individuals may experience difficulty performing tasks that require sustained attention, head movement, or upper limb function [61–65].

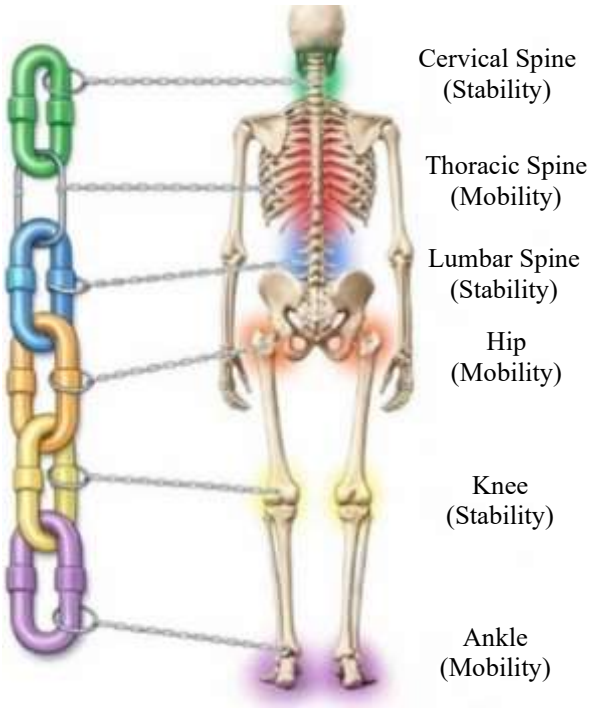


Figure 7. Kinetic chain involvement from cervical spine to thoracic and shoulder regions.

Table 2 summarizes the range of clinical manifestations associated with Text Neck Syndrome, categorizing them into pain-related symptoms, neurological signs, and functional limitations. Pain-related manifestations include localized neck pain, shoulder discomfort, and upper back pain, all of which are exacerbated by prolonged device use and poor posture. Neurological signs encompass tingling, numbness, and radiating pain, reflecting the involvement of nerve roots and potential compression within the cervical spine. Functional limitations may include reduced range of motion, decreased muscle strength and endurance, and impaired ability to maintain proper posture during daily activities. Over time, if these symptoms are not addressed, long-term consequences may develop, including degenerative disc disease, which results from chronic disc compression and reduced hydration of intervertebral discs. Cervical radiculopathy may also occur due to progressive narrowing of neural foramina and increased pressure on nerve roots, leading to persistent neurological symptoms and functional impairment. Chronic musculoskeletal pain is another significant outcome, as continuous mechanical stress and muscle imbalance create a cycle of pain and dysfunction that can become difficult to reverse. Furthermore, studies have shown that a considerable proportion of individuals with Text Neck Syndrome experience measurable levels of neck disability, indicating that the condition can have a substantial impact on quality of life and daily functioning. In younger populations, early onset of these symptoms raises concerns about long-term spinal health, as prolonged exposure to poor postural habits may accelerate degenerative changes and increase the risk of chronic conditions later in life [66].

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Table 2. Clinical manifestations of text neck syndrome.

Clinical manifestation	Description	Affected region	Functional impact
Neck pain	Dull or sharp pain due to sustained forward head posture	Cervical spine	Reduced neck mobility and discomfort.
Shoulder pain	Muscle strain from prolonged device use	Shoulder girdle	Limited arm movement and fatigue.
Upper back pain	Increased thoracic kyphosis leading to muscular strain	Thoracic spine	Postural imbalance and stiffness.
Headaches	Tension-type headaches from suboccipital muscle tightness	Occipital and frontal regions	Reduced concentration and productivity.
Forward head posture	Anterior displacement of the head relative to the spine	Cervical and upper thoracic spine	Altered biomechanics and increased spinal load.
Rounded shoulders	Protracted shoulder position due to muscular imbalance	Shoulder girdle	Decreased scapular stability.
Muscle fatigue	Overuse of neck and shoulder muscles	Cervical and scapular muscles	Reduced endurance and performance.
Reduced range of motion	Limited cervical flexion, extension, and rotation	Cervical spine	Difficulty in daily activities.
Tingling or numbness	Nerve compression or irritation	Upper limbs	Sensory disturbances and discomfort.
Eye strain	Prolonged screen exposure and poor visual ergonomics	Eyes	Visual fatigue and discomfort.
Dizziness	Altered cervical proprioception	Cervical spine and vestibular link	Balance issues and instability.
Postural imbalance	Misalignment of head, neck, and shoulders	Whole upper quarter	Increased risk of musculoskeletal disorders.

ROLE OF MUSCLE ACTIVITY AND FATIGUE

Altered muscle activation patterns play a central role in the development and progression of Text Neck Syndrome, particularly in individuals with prolonged smartphone use, where sustained static postures disrupt normal neuromuscular coordination and lead to fatigue and decreased muscular endurance. During extended device use, the cervical extensor muscles remain continuously active to counterbalance the forward displacement of the head, resulting in increased muscular load and progressive fatigue over time. Experimental evidence has shown that maintaining a flexed neck posture significantly increases activation levels in muscles, such as the upper trapezius and splenius capitis, particularly in positions involving maximum bending, thereby accelerating fatigue compared to neutral postures. At the same time, prolonged smartphone use has been associated with reduced activation of stabilizing muscles, particularly the deep cervical flexors, which are essential for maintaining segmental stability and proper alignment of the cervical spine. This reduction in stabilizer activity compromises spinal support and shifts the mechanical burden to superficial muscles, which are less efficient for sustained postural control. Figure 8 illustrates these changes in muscle activity and fatigue patterns, showing how decreased function of deep stabilizers is accompanied by increased reliance on superficial musculature, leading to inefficient load distribution and rapid onset of fatigue [67–70].

Sustained low-level muscle contraction, even at relatively low percentages of maximum voluntary contraction, has been shown to contribute to discomfort and perceived fatigue, particularly in the neck and upper back regions during prolonged smartphone tasks. Although some studies suggest that myoelectric indicators of fatigue may not always show consistent patterns, subjective reports of discomfort and fatigue increase significantly with duration of device use, indicating the cumulative impact of sustained loading. The imbalance between reduced stabilizer activity and overactive superficial muscles creates a cycle in which inefficient muscle recruitment patterns further exacerbate fatigue and reduce endurance capacity. Overactivity of superficial muscles, such as the upper trapezius and levator scapulae, leads to increased metabolic demand, reduced blood flow, and accumulation of

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metabolic byproducts, all of which contribute to muscle fatigue and discomfort. Additionally, prolonged static posture limits normal muscle relaxation cycles, preventing adequate recovery and leading to sustained muscle tension and stiffness. These changes not only affect muscle performance but also influence spinal loading patterns, as fatigued muscles are less capable of providing adequate support and shock absorption, thereby increasing stress on passive structures such as ligaments and intervertebral discs.

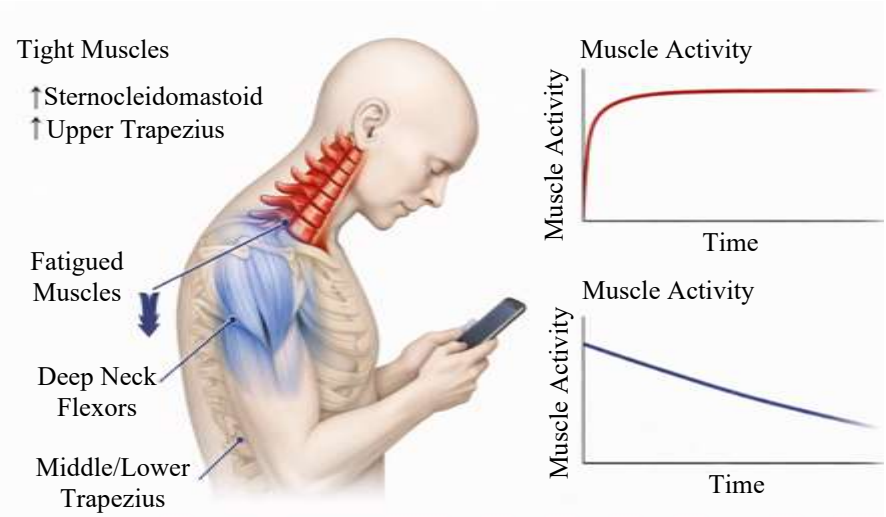


Figure 8. Changes in muscle activity and fatigue patterns during prolonged device use.

Table 3 summarizes these biomechanical alterations by highlighting changes in spinal loading, muscle activity, and posture associated with Text Neck Syndrome. It demonstrates how increased anterior loading of the cervical spine, combined with altered muscle activation patterns, contributes to inefficient biomechanics and progressive dysfunction. Furthermore, prolonged smartphone use has been linked to decreased muscle endurance, particularly in the cervical extensors, which are required to sustain head position during forward flexion. Reduced endurance capacity leads to earlier onset of fatigue, which in turn promotes compensatory movements and further disrupts normal movement patterns. These compensatory strategies often involve increased reliance on accessory muscles, resulting in inefficient movement and additional strain on the musculoskeletal system. Over time, the cumulative effects of altered muscle activation, fatigue, and reduced endurance contribute to chronic musculoskeletal dysfunction, reduced functional capacity, and increased risk of injury, emphasizing the need for early intervention and corrective strategies to restore optimal muscle function and spinal stability [71].

Table 3. Biomechanical changes associated with text neck syndrome.

Biomechanical change	Description	Affected structure	Functional consequence
Increased cervical flexion angle	Forward head position increases angle of neck flexion	Cervical spine	Elevated mechanical load on vertebrae and discs.
Increased compressive forces	Greater load on cervical discs with head tilt	Intervertebral discs	Accelerated disc degeneration and risk of herniation.
Altered cervical curvature	Reduction or reversal of normal lordotic curve	Cervical spine	Postural instability and chronic pain.
Muscle imbalance	Tight anterior and superficial muscles with weak deep stabilizers	Neck and shoulder muscles	Poor postural control and fatigue.
Scapular dyskinesis	Abnormal movement of scapula due to muscle imbalance	Scapulothoracic joint	Shoulder dysfunction and reduced upper limb efficiency.
Increased thoracic kyphosis	Excessive curvature of upper back	Thoracic spine	Compensatory cervical strain and postural deviation.

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Ligamentous strain	Prolonged stress on cervical ligaments	Cervical ligaments	Reduced stability and increased injury risk.
Reduced shock absorption	Impaired ability of spine to distribute mechanical loads	Vertebral column	Higher susceptibility to microtrauma.
Joint stiffness	Reduced mobility of cervical facet joints	Cervical facet joints	Limited range of motion and discomfort.
Proprioceptive impairment	Altered sensory feedback from cervical structures	Neuromuscular system	Poor coordination and balance.
Nerve compression	Mechanical pressure on cervical nerve roots	Cervical nerves	Pain, tingling, and numbness in upper limbs.
Increased energy expenditure	Greater muscular effort to maintain posture	Neck and shoulder musculature	Early fatigue and decreased functional performance.

PREVENTION AND BIOMECHANICAL CORRECTION STRATEGIES

Effective management of Text Neck Syndrome requires a multifaceted approach that integrates ergonomic correction, targeted therapeutic exercises, and behavioral modifications to address both the underlying biomechanical dysfunction and contributing lifestyle factors. Ergonomic interventions play a foundational role in reducing mechanical strain on the cervical spine, particularly by ensuring that digital devices are positioned at eye level to minimize forward head posture and maintain neutral spinal alignment. Proper workstation setup, including adjustable chairs, appropriate desk height, and supportive backrests, further helps distribute loads evenly across the spine and reduce cumulative stress on cervical structures. Posture correction strategies are equally critical, as conscious alignment of the head over the shoulders and maintenance of cervical lordosis reduce abnormal loading and improve muscular efficiency. Strengthening exercises targeting deep neck flexors, such as chin tuck exercises, are essential for restoring segmental stability and counteracting the effects of prolonged flexion. Simultaneously, stretching of shortened muscles including the upper trapezius, levator scapulae, and pectoralis minor helps relieve tension and correct muscle imbalances associated with forward head posture. Incorporating thoracic extension and scapular stabilization exercises further enhances postural alignment by addressing the interconnected nature of cervical and upper back mechanics. In addition to strengthening and flexibility training, neuromuscular re-education techniques improve proprioception and coordination, enabling individuals to maintain proper posture during functional activities. Behavioral modifications are a crucial component of long-term management, as reducing screen time and avoiding prolonged static postures help prevent recurrence of symptoms. Regular movement breaks, such as the implementation of micro-breaks every 20–30 minutes, allow for muscle relaxation and recovery, thereby reducing fatigue and improving circulation. Simple strategies, such as alternating device positions, using voice commands, or holding devices at eye level, can significantly decrease cervical strain during daily activities. Education and awareness also play an important role, as individuals who understand the impact of posture and device use are more likely to adopt healthier habits and maintain compliance with preventive strategies. Furthermore, integrating general physical activity and aerobic exercise into daily routines contributes to overall musculoskeletal health and enhances resilience against repetitive strain injuries. In clinical settings, physiotherapy interventions may include manual therapy, soft tissue mobilization, and individualized exercise programs tailored to the severity of symptoms and functional limitations. Advanced rehabilitation approaches, such as spinal decompression exercises and neuromuscular training, have also shown promising outcomes in reducing pain and improving functional capacity in individuals with Text Neck Syndrome.

CONCLUSION

Text Neck Syndrome is a growing musculoskeletal concern that arises from prolonged use of handheld digital devices, leading to sustained forward head posture and altered spinal alignment. This condition significantly disrupts the normal biomechanics of the cervical spine by increasing mechanical stress on vertebral structures, intervertebral discs, and supporting ligaments. As the head moves forward, the effective load on the cervical spine increases, resulting in excessive strain and potential degeneration over time. Alongside these structural changes, there is a clear pattern of muscular imbalance, where superficial muscles, such as the upper trapezius and sternocleidomastoid, become

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overactive and tight, while deep cervical flexors and scapular stabilizers become weak and inhibited. These imbalances impair postural stability and reduce the efficiency of movement. The effects are not limited to the cervical region but extend to the thoracic spine and shoulder complex, contributing to increased thoracic kyphosis and scapular dysfunction. This interconnected dysfunction highlights the need for a comprehensive and holistic approach to both assessment and intervention. Addressing Text Neck Syndrome requires an understanding of its underlying biomechanical mechanisms in order to design effective preventive strategies and targeted rehabilitation programs suited for individuals in the modern digital environment.

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