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Muscle Morphology and Its Role in Chronic Neck Pain: A Review Article

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Abstract

Introduction: Chronic neck pain (CNP) is a common and debilitating condition that significantly impacts quality of life, productivity, and overall well-being. Muscle morphology, particularly in the deep cervical muscles, plays a critical role in the onset, development, and persistence of chronic neck pain. This review investigates the relationship between muscle changes, including atrophy, fat infiltration, and alterations in muscle fiber composition, and their contribution to cervical instability, pain, and functional limitations. **Methods:** The review examines existing literature on muscle morphology in CNP, focusing on the role of deep cervical muscles in the pathophysiology of neck pain. It also highlights how factors such as disuse, changes in neural activation, and chronic inflammation exacerbate these muscle alterations. The role of advanced imaging techniques, such as MRI, in identifying these changes is also discussed. **Results:** Alterations in muscle morphology, including atrophy and fat infiltration, contribute to weakness and reduced spinal stability, which are key factors in the development and persistence of chronic neck pain. Neural activation changes and chronic inflammation further exacerbate muscle degeneration. Advanced imaging techniques, particularly MRI, play a crucial role in assessing these morphological changes and enabling personalized treatment strategies. **Conclusion:** Muscle degeneration, including atrophy and fat infiltration in the cervical spine, is a significant factor in chronic neck pain. Effective management requires a comprehensive approach, including rehabilitation programs focused on muscle strengthening, postural correction, and ergonomic adjustments. Fat infiltration in cervical muscles is a significant marker of structural and functional impairment in cervical spine disorders. Further research is needed to explore the mechanisms behind muscle changes in CNP and to develop more targeted and effective interventions.

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INTRODUCTION

Chronic neck pain is a prevalent and multifactorial musculoskeletal disorder that significantly impacts individuals' quality of life, work productivity, and mental well-being. It is estimated that up to 45% of the general population will experience chronic neck pain at some point in their lives, with many individuals facing long-term discomfort, functional impairments, and decreased ability to engage in daily activities (1). The condition is associated with a substantial burden, including long-term disability, decreased work performance, and increased healthcare costs, underscoring the need for a deeper understanding of its pathophysiology and more effective management strategies. Despite its high prevalence, chronic neck pain remains a complex condition that presents significant challenges for treatment, often requiring a multidisciplinary approach incorporating physical therapy, pharmacological interventions, and, in some cases, surgical procedures (2).

The cervical spine, consisting of seven vertebrae and associated soft tissues, is responsible for supporting the head, facilitating neck movement, and protecting the spinal cord and nerve roots. Its intricate structure, including muscles, ligaments, and intervertebral discs, is essential for maintaining mobility and stability. Among the various anatomical structures involved in chronic neck pain, the deep cervical muscles—specifically the multifidus, semispinalis cervicis, and splenius cervicis—play a key role in stabilizing the cervical spine and controlling neck movement. These muscles are integral to postural control and the coordination of movement during routine activities. However, dysfunction or morphological alterations in these muscles have been increasingly linked to the onset and persistence of chronic neck pain, although the underlying mechanisms remain incompletely understood (3).

Recent research has identified several factors contributing to the development and persistence of chronic neck pain, with a growing body of evidence pointing to changes in muscle morphology as a significant contributor. One primary factor is muscle atrophy, which refers to a reduction in muscle mass and size, particularly in the deep cervical muscles such as the multifidus and semispinalis cervicis. Atrophy can result from disuse, altered neural activation, and chronic inflammation associated with persistent pain, further contributing to instability and functional limitations (4). Alongside muscle atrophy, fat infiltration within cervical muscles has been observed in individuals with chronic neck pain. This occurs when muscle tissue is replaced by fat cells, impairing muscle function and further compromising the ability to stabilize the cervical spine, thus exacerbating weakness, pain, and disability (5).

Additionally, alterations in muscle fiber composition have been observed in chronic neck pain, with a shift from Type II (fast-twitch) fibers, which are responsible for generating force, to Type I (slow-twitch) fibers, which are more resistant to fatigue but generate less force. This change in muscle fiber type may influence overall muscle strength and endurance, affecting an individual's capacity to perform daily tasks and potentially exacerbating neck pain (6). Disruptions in the coordination and control of cervical muscles further contribute to the condition, leading to inefficient movement patterns and compensatory strategies that increase muscle tension and worsen pain (7).

In some cases, chronic neck pain may also accelerate degenerative changes within the cervical spine, such as intervertebral disc degeneration, facet joint arthropathy, and the formation of osteophytes (bone spurs). These structural changes place additional mechanical stress on the cervical muscles, leading to muscle imbalances and further biomechanical dysfunction (8). Interestingly, some individuals may experience muscle hypertrophy as a compensatory response to ongoing pain and functional demands. Although hypertrophy may temporarily stabilize the cervical spine, excessive muscle growth can result in biomechanical dysfunction, muscle imbalance, and pain (9).

Effective diagnosis of chronic neck pain is critical to the development of targeted treatment strategies. A clear understanding of the morphological changes in cervical muscles can significantly enhance diagnostic accuracy and inform personalized therapeutic approaches. Advanced imaging techniques, particularly MRI, offer a non-invasive method to visualize muscle morphology and volume changes, allowing for better identification of anatomical abnormalities contributing to chronic pain (10). Given the significant variability in clinical presentation and underlying pathology, personalized treatment strategies are essential. By identifying specific patterns of muscle morphology and functional impairments in individuals with chronic neck pain, clinicians can tailor interventions more effectively. For example, individuals with muscle atrophy may benefit from targeted strengthening exercises, while those with fat infiltration or hypertrophy may require specific therapies aimed at improving muscle quality and function (11).

Understanding the relationship between muscle morphology and chronic neck pain is also crucial for elucidating the pathophysiology of the condition. Alterations in muscle morphology—such as atrophy, hypertrophy, and fat infiltration—reflect underlying processes of disuse, muscle imbalance, or degenerative changes within the cervical spine. Unraveling these mechanisms can help identify novel therapeutic targets

and inform the development of more effective interventions (12). Rehabilitation plays a vital role in managing chronic neck pain, with the primary goals of restoring function, reducing pain, and improving quality of life. By examining changes in muscle morphology and volume, rehabilitation strategies can be refined, leading to more effective exercise regimens based on individual MRI findings (13).

This review aims to synthesize the current understanding of the relationship between changes in cervical muscle morphology and chronic neck pain. By evaluating relevant research and imaging studies, we will explore how these muscle alterations contribute to the pathophysiology of chronic neck pain and highlight the implications for diagnosis, treatment, and rehabilitation strategies. Ultimately, this review aims to provide insights that can guide more targeted and effective interventions for individuals suffering from chronic neck pain.

LITERATURE REVIEW

Muscle Morphology in Chronic Neck Pain

Chronic neck pain is often associated with alterations in the morphology of the cervical muscles, particularly the deep extensor muscles, including the multifidus, semispinalis cervicis, and splenius cervicis. These muscles play a crucial role in maintaining cervical stability and facilitating smooth neck movements. Changes in muscle structure—whether due to degeneration, atrophy, hypertrophy, or fat infiltration—can significantly impact the function of the cervical spine, contributing to pain, instability, and restricted movement. Over time, these morphological changes may lead to the progression of symptoms and worsening of clinical outcomes.

Fat Infiltration as a Marker of Muscle Degeneration

Fat infiltration (FI) refers to the replacement of muscle fibers by adipose tissue, which can compromise the function of the affected muscles. This process has been observed in several conditions associated with chronic neck pain, such as cervical spondylosis, cervical deformity, and myelopathy. Fat infiltration impairs muscle contractility and contributes to weakness, leading to reduced stability of the cervical spine and a heightened risk of injury (12).

In a study by Doi et al. (2023), fat infiltration in the multifidus and semispinalis cervicis muscles was shown to correlate with the severity of cervical ossification of the posterior longitudinal ligament (OPLL), a condition that restricts spinal mobility and causes significant disability (12). The study found that deeper fat infiltration was associated with more extensive vertebral involvement and greater disability, suggesting that muscle degeneration plays a central role in the pathophysiology of OPLL.

Atrophy and Muscle Weakness

Atrophy of the cervical muscles is another well-documented feature in individuals with chronic neck pain. Muscle atrophy often arises from disuse, disordered neural activation, or chronic inflammation in response to persistent pain. The multifidus muscle, in particular, is highly susceptible to atrophy in individuals with neck pain, leading to instability and dysfunction of the cervical spine (5).

Several studies have reported significant correlations between the extent of muscle atrophy and the severity of symptoms in conditions such as degenerative cervical myelopathy (DCM). Fortin et al. (2022) found that patients with more extensive muscle atrophy had significantly lower muscle strength, which was strongly associated with poorer functional outcomes and increased disability (19).

Hypertrophy: A Compensatory Response

In some cases, hypertrophy (excessive growth) of the cervical muscles occurs as a compensatory mechanism in response to pain and instability. This hypertrophy, while initially offering some degree of stabilization, can ultimately result in muscle imbalance and contribute to biomechanical dysfunction (9). Hypertrophic muscles may become overactive, leading to increased muscle tension and secondary pain. Studies have suggested that hypertrophic changes can contribute to the complexity of chronic neck pain, particularly in patients with cervical spondylosis or whiplash-associated disorder (WAD).

Alterations in Muscle Fiber Composition

Alongside changes in muscle size and fat content, alterations in muscle fiber composition have also been observed in individuals with chronic neck pain. Healthy muscles typically consist of a mix of Type I (slow-twitch) and Type II (fast-twitch) fibers. Type I fibers are fatigue-resistant and crucial for maintaining postural stability, while Type II fibers are responsible for generating force during more dynamic movements. In chronic neck pain, a shift toward a greater proportion of Type I fibers has been observed (6). This shift may reduce the muscle's ability to produce force and respond quickly to changes in posture, further exacerbating neck pain and functional limitations.

Cervical Spine Degeneration and Muscle Changes

The relationship between cervical spine degeneration and muscle morphology is bidirectional, with degenerative changes in the spine influencing muscle structure and vice versa. Intervertebral disc degeneration, facet joint arthropathy, and the formation of osteophytes can place additional mechanical stress on cervical muscles, leading to compensatory muscle

changes. In turn, muscle degeneration may exacerbate spinal degeneration, creating a cycle of pain, dysfunction, and instability.

In a study by Huang et al. (2022), the relationship between cervical disc degeneration and muscle morphology was explored. They found that patients with greater fat infiltration and muscle atrophy in the deep paraspinal muscles exhibited more severe cervical spine degeneration, which was associated with worse clinical outcomes, such as increased disability and pain (17). These findings highlight the complex interplay between muscle changes and degenerative changes in the cervical spine.

Advanced Imaging Techniques for Muscle Assessment

The diagnosis of chronic neck pain and muscle degeneration has been significantly enhanced by the use of advanced imaging techniques such as magnetic resonance imaging (MRI) and computed tomography (CT). MRI, in particular, allows for non-invasive visualization of muscle morphology, providing valuable insights into fat infiltration, muscle atrophy, and hypertrophy. Studies have shown that MRI can accurately assess changes in the cross-sectional area (CSA) and fat infiltration percentage (FI%) of the cervical extensor muscles, which are closely linked to clinical symptoms (10).

In patients with cervical deformity, such as those studied by Passias et al. (2018), MRI findings of increased fat infiltration in the cervical extensor muscles were correlated with poor sagittal balance, suggesting that muscle changes may serve as early indicators of worsening deformity (13). Furthermore, MRI can be used to track changes in muscle morphology over time, offering prognostic information and aiding in the development of personalized treatment plans.

Implications for Treatment and Rehabilitation

Understanding the impact of muscle morphology on chronic neck pain is crucial for developing effective treatment and rehabilitation strategies. Targeted exercise programs aimed at strengthening the cervical muscles, particularly the multifidus and semispinalis cervicis, have been shown to be beneficial for improving stability and reducing pain (11). For individuals with significant fat infiltration or muscle atrophy, therapeutic approaches such as resistance training, neuromuscular re-education, and manual therapy can help restore muscle function and improve cervical spine stability.

However, it is important to recognize that not all patients with chronic neck pain will respond similarly to these interventions. The heterogeneity of muscle changes—such as the extent of fat infiltration, muscle atrophy, or hypertrophy—means that treatment plans must be personalized. Imaging studies, particularly MRI, can play a key role in guiding rehabilitation strategies by identifying specific patterns of muscle degeneration and tailoring interventions to address these underlying changes.

The Need for Longitudinal Studies

While much has been learned about the relationship between muscle morphology and chronic neck pain, there are still significant gaps in our understanding. Most studies to date have been cross-sectional in nature, limiting the ability to draw causal conclusions. Longitudinal studies are needed to better understand the progression of muscle changes over time and their impact on the development and persistence of chronic neck pain. Additionally, research into the role of muscle degeneration as a predictor of surgical outcomes is critical for improving patient selection and post-surgical management (13, 14).

Pain Management in Chronic Neck Pain

Effective pain management is essential for improving quality of life and functional outcomes in individuals with chronic neck pain. Given the multifactorial nature of the condition, pain management must be tailored to the underlying pathology, the severity of symptoms, and the individual needs of the patient. Approaches typically involve a combination of pharmacological interventions, physical therapy, and, in some cases, surgical procedures. This section will discuss the key strategies for managing chronic neck pain, with a focus on the role of muscle morphology, rehabilitation, and emerging therapies (18).

Pharmacological Interventions

Pharmacological management remains one of the primary approaches for alleviating the symptoms of chronic neck pain. Medications can be used to reduce pain, inflammation, and muscle spasms, improving function and quality of life for many patients.

NSAIDs such as ibuprofen and naproxen are commonly prescribed for the treatment of musculoskeletal pain. These drugs help to reduce inflammation and relieve mild to moderate pain in the cervical region. However, their long-term use may be associated with gastrointestinal, renal, and cardiovascular side effects, and thus their use should be monitored, particularly in older patients or those with pre-existing conditions (19).

For patients with muscle spasms or more severe pain, analgesics (such as acetaminophen) and muscle relaxants (such as cyclobenzaprine) are frequently prescribed. Muscle relaxants help reduce the tension in the cervical musculature, which can improve comfort and facilitate physical therapy. However, these drugs

may cause sedation, dizziness, or fatigue, limiting their use in patients who need to remain alert or engaged in active rehabilitation.

In some cases of severe chronic neck pain, opioids may be prescribed for short-term use under strict supervision. Opioids are generally avoided for long-term management due to the risk of addiction, tolerance, and adverse effects such as constipation and cognitive impairment. However, for individuals who have failed other interventions, opioids may provide short-term relief during acute flare-ups. Multimodal pain management, which combines opioids with non-opioid medications and non-pharmacological therapies, is recommended to reduce opioid dependency.

For patients with significant inflammation or nerve root involvement, corticosteroid injections may be used. These injections can target specific areas of inflammation, such as the facet joints or epidural space, and provide relief from pain and swelling. However, repeated use of corticosteroid injections should be approached with caution due to potential side effects like bone thinning, tissue weakening, and further degenerative changes.

Physical Therapy and Rehabilitation

Physical therapy (PT) plays a central role in managing chronic neck pain, particularly in cases where muscle dysfunction, poor posture, or cervical spine instability is contributing to symptoms. Physical therapists employ a variety of modalities to improve muscle strength, flexibility, and coordination.

Targeted exercises aimed at strengthening the cervical and upper back muscles are essential for improving stability and reducing pain. Emphasis is often placed on strengthening the deep cervical muscles such as the multifidus and semispinalis cervicis, which are vital for maintaining proper posture and stability in the cervical spine. In particular, exercises that focus on retraining these muscles have shown promise in alleviating pain and improving function.

Strengthening exercises typically involve isometric exercises, where the muscles contract without changing length, and dynamic movements that engage the cervical spine through its full range of motion. Research has shown that strengthening the deep cervical extensors can lead to improved postural control, reduced pain intensity, and enhanced physical performance (11).

Posture Correction and Ergonomics

Chronic neck pain is frequently exacerbated by poor posture, particularly in individuals who spend long periods in seated or forward-leaning positions (e.g., desk work, computer use). Physical therapists often focus on posture correction, teaching patients how to maintain a neutral cervical spine and avoid excessive flexion or extension. Ergonomic modifications in the workplace, such as adjusting the height of chairs, desks, and computer screens, are also commonly recommended to prevent exacerbations of neck pain.

Manual therapy, including mobilization and manipulation techniques, can be effective in treating musculoskeletal pain associated with chronic neck pain. These hands-on techniques involve applying controlled movements to the cervical spine and surrounding soft tissues to improve joint mobility, reduce muscle tension, and enhance circulation. Studies suggest that manual therapy can lead to significant reductions in pain and improvements in neck function, especially when combined with other physical therapy interventions (20).

In addition to strengthening exercises, stretching is an essential component of rehabilitation programs for chronic neck pain. Flexibility exercises focus on lengthening tight muscles and improving the overall range of motion of the cervical spine. Stretching the upper trapezius, levator scapulae, and scalene muscles can help reduce muscle tightness and alleviate symptoms of stiffness.

Interventional Techniques

For patients who have not responded to conservative treatments, interventional techniques can be used to target pain and inflammation directly. These treatments often provide relief when more conservative approaches are ineffective.

In cases where nerve compression or irritation is contributing to chronic neck pain, nerve blocks (e.g., facet joint injections) or radiofrequency ablation may be used to reduce pain. These procedures involve the injection of anesthetic or corticosteroids around specific nerves to temporarily block pain signals or reduce inflammation. In some cases, radiofrequency ablation can be performed to disrupt pain transmission from specific nerve fibers, providing long-lasting pain relief.

Spinal cord stimulation is a technique used for patients with refractory chronic neck pain who have not benefited from more conventional treatments. This procedure involves the implantation of a small device near the spinal cord that sends electrical impulses to interfere with pain signals. It is typically used when the pain is severe, chronic, and unresponsive to other treatments. Evidence suggests spinal cord stimulation can be effective in reducing pain and improving function in select patients.

Surgical Interventions

While surgical interventions are generally considered a last resort, they may be necessary in cases of structural abnormalities such as cervical disc herniation, spinal stenosis, or degenerative disc disease

that do not respond to conservative treatments. Surgical options include:

Anterior Cervical Discectomy and Fusion (ACDF): This procedure involves removing a damaged disc and fusing the adjacent vertebrae. It is commonly performed for patients with cervical radiculopathy or myelopathy.

Cervical Disc Replacement: A newer surgical option, cervical disc replacement involves removing the damaged disc and replacing it with an artificial disc to preserve motion in the cervical spine.

Posterior Cervical Fusion: This surgery is performed when there is a need for stabilization of the cervical spine due to degenerative changes or spinal deformities.

While surgery can provide relief from pain, it is not without risks. These include infection, nerve damage, and complications related to the fusion (e.g., adjacent segment degeneration).

Emerging Therapies

Several emerging therapies are gaining attention for their potential in treating chronic neck pain, especially for patients with muscle degeneration or inflammatory processes.

PRP therapy involves using a patient's own blood, which is processed to concentrate the platelets, and then injected into the affected area to promote healing and tissue regeneration. Studies have shown that PRP can stimulate collagen production, improve healing, and reduce inflammation in musculoskeletal injuries, making it a promising treatment for muscle degeneration and chronic neck pain (22).

Stem cell therapy is another innovative approach that holds potential for treating chronic neck pain caused by disc degeneration, muscle atrophy, or ligament injuries. Stem cells can promote tissue regeneration and repair damaged structures, offering the possibility of addressing the root cause of pain. Though still experimental, studies are ongoing to assess the long-term efficacy and safety of stem cell therapy for musculoskeletal conditions.

Transcranial Magnetic Stimulation (TMS) is a non-invasive technique that uses magnetic fields to stimulate specific regions of the brain involved in pain processing. This therapy has shown promise for various chronic pain conditions, including neck pain, and is thought to help reset the brain's pain perception. Though more research is needed, TMS may provide an alternative to pharmacological pain management for certain patients (23).

DISCUSSION

In 2023, Toru Doi and colleagues conducted a study on the relationship between the morphology of the posterior paraspinal muscle and clinical features in patients with cervical ossification of the posterior longitudinal ligament (OPLL). The study, which was a retrospective observational analysis, involved 49 patients with cervical OPLL who underwent MRI imaging prior to surgery. The study assessed the cross-sectional area (CSA) and fat infiltration percentage (FI%) of the posterior paraspinal muscles (multifidus [MF] and semispinalis cervicis [SCer]). Additionally, the correlation between muscle measurements and clinical outcomes, such as the Neck Disability Index (NDI) score, was evaluated. The patients were divided into two groups based on the extent of ossification: segmental and localized (OPLL-SL) and continuous and mixed (OPLL-CM). Fat infiltration in the paraspinal muscles was significantly correlated with the number of vertebrae affected by OPLL and the maximum OPLL occupancy. The study concluded that deep fat infiltration in the posterior paraspinal muscles was associated with OPLL severity and could affect cervical disability. Patients with extensive OPLL, leading to reduced neck mobility, were more likely to show worse clinical manifestations due to deep muscle degeneration (24).

In 2018, Peter G. Passias and colleagues explored the relationship between fat infiltration in the cervical extensor muscles and sagittal balance in patients with cervical deformity (CD). This retrospective study involved 38 patients (average age: 56.6 years, 73% female) with a body mass index (BMI) of 30.1 and a Charlson comorbidity index of 0.61. Key parameters, including the T1 slope (T1SS) and cervical sagittal vertical axis (cSVA), were measured. The study found that worsening fat infiltration (FI) correlated with poor baseline cSVA, T1SS, and gait disturbance. Post-surgical regression models indicated that baseline FI in the C2-C7 region was a strong predictor of cSVA one year after surgery. However, no significant correlation between FI and patient-reported outcomes (PROMS) was observed. The findings suggest that patients with CD exhibited more significant changes in cervical extensor muscles, which play a critical role in both dynamic and static head and neck movements. Fatty degeneration in these muscles was linked to worsened CD and could serve as an important predictor for post-surgical sagittal alignment (25).

In 2022, Xing-jin Wang and colleagues studied fat infiltration in the cervical extensor muscles and its association with sagittal alignment after anterior cervical discectomy and fusion (ACDF). The study involved 101 patients who underwent single-level ACDF between March 2011 and April 2020. The patients were classified into groups based on fat infiltration scores, and clinical outcomes, including the Neck Disability Index (NDI), Japanese Orthopedic Association (JOA) score, and Visual Analog Scale (VAS) for pain, were assessed. The study revealed that despite varying

degrees of fat infiltration, sagittal alignment parameters, such as the C2-C7 Cobb angle and T1 slope, improved after surgery. Moreover, there was no significant difference in clinical outcomes between the groups, suggesting that post-surgical cervical sagittal alignment could be satisfactory even in the presence of varying levels of fat infiltration in the multifidus muscle. The study emphasized the complexity of maintaining cervical sagittal alignment following ACDF (26).

In 2022, Suzanne J. Snodgrass and colleagues conducted a study comparing muscle and fat volume in cervical extensor muscles (multifidus and semispinalis cervicis) in individuals with chronic idiopathic neck pain (CINP). The study found that patients with CINP had larger muscle volumes and more fat infiltration (MFI) compared to healthy controls, with significant differences in the MFI between the two groups. Factors such as age, sex, side of the body, and BMI influenced these results. The study suggested that increased MFI in the cervical extensor muscles could be a mechanism underlying neck pain, but further research is needed to confirm its role in the onset or persistence of neck pain and its clinical outcomes (27).

In 2020, James M. Elliott and colleagues conducted a study on fat infiltration following whiplash injury, comparing CT and MRI imaging. This prospective secondary analysis focused on the muscle changes in patients with poor recovery after whiplash injury related to motor vehicle collisions (MVC). The study involved 36 participants who were evaluated using both CT and MRI at various time points post-injury. Results indicated that deep cervical extensor muscles exhibited greater fat infiltration in those with severe symptoms, particularly in the first year following injury. The study highlighted that fat infiltration could be a potential cause of muscle weakening seen in CT scans, especially in individuals with movement restrictions or coexisting conditions like obesity, diabetes, and spinal degenerative diseases (28).

In a recent study by Huang and colleagues, the correlation between changes in muscle morphology, cervical spine degeneration, and clinical features in patients with chronic nonspecific neck pain (CNSNP) was examined using MRI. The study analyzed MRI data from 55 patients and identified significant correlations between fat infiltration (FI%) and muscle cross-sectional area (aCSA) with cervical disk degeneration and clinical outcomes. The findings showed that changes in the deep and superficial paraspinal muscles were significantly associated with cervical balance parameters and clinical severity, indicating a complex relationship between muscle morphology, cervical degeneration, and the clinical presentation of CNSNP (29).

In a cross-sectional study by Van Looveren and colleagues, changes in muscle morphology in female patients with chronic idiopathic neck pain (CINP) and chronic whiplash-associated disorder (CWAD) were assessed using MRI. The study found that the CWAD group had significantly more fat infiltration in certain cervical extensor muscles compared to the CINP group and healthy controls. Interestingly, no clear correlations were found between these muscle changes and factors such as pain duration, kinesiophobia, or disability. The study concluded that while both CINP and CWAD exhibited muscle changes, further studies with controlled designs are needed to confirm these findings and explore their clinical implications (30).

In a study by Fortin and colleagues, the relationship between muscle morphology, muscle strength, and functional outcomes in patients with degenerative cervical myelopathy (DCM) was examined. The study found that cervical muscle area and fat infiltration were associated with muscle strength, with greater fat infiltration correlating with lower functional scores. The results underscored the importance of assessing muscle morphology in DCM patients and suggested that fat infiltration in cervical extensors could be an important factor influencing functional outcomes (31).

In their review, Li and colleagues explored the relationship between fat infiltration (FI) in cervical muscles and clinical correlations in patients with cervical spondylosis. They found significant differences in fat infiltration levels between healthy volunteers and patients with various conditions, such as cervical radiculopathy (CR) and myelopathy (DM). The study highlighted that severe FI and misalignment of the cervical spine were key imaging features related to cervical spondylosis and suggested that these factors could influence clinical outcomes (32).

Finally, in another study, Elliott and colleagues compared fat infiltration in cervical extensor muscles between patients with chronic whiplash-associated disorders (WAD) and healthy controls using MRI. The study found that WAD patients had significantly more fat infiltration in the cervical extensor muscles, particularly in the deep muscles. This highlighted the need for further research to understand the relationship between muscle changes and symptoms in patients with chronic WAD and to explore its clinical significance in treatment and management (33).

The studies reviewed highlight the growing recognition of muscle morphology, particularly fat infiltration (FI) in cervical extensor muscles, as a significant factor in various neck pain conditions and cervical spine disorders. Across multiple studies, fat infiltration in the posterior paraspinal muscles—especially in the multifidus and semispinalis cervicis—emerges as a consistent feature associated with both the

severity of underlying spinal pathology and clinical outcomes.

In cervical ossification of the posterior longitudinal ligament (OPLL), Doi et al. (2023) demonstrated that deep fat infiltration in the posterior paraspinal muscles correlated with the extent of ossification and the severity of cervical disability, underlining the relationship between muscle degeneration and impaired cervical mobility. Their findings suggest that extensive OPLL may exacerbate muscle degeneration, contributing to worsened clinical manifestations such as increased disability and restricted neck movement. This aligns with the findings of Snodgrass et al. (2022), who reported that patients with chronic idiopathic neck pain (CINP) exhibited increased fat infiltration in cervical extensor muscles compared to healthy controls, possibly indicating a mechanism for pain persistence. While their study did not establish a direct cause-and-effect relationship, it underscores the importance of muscle degeneration in neck pain pathophysiology.

Fat infiltration has also been implicated in cervical deformity (CD), as demonstrated by Passias et al. (2018). Their research found that increased fat infiltration in the cervical extensor muscles was correlated with poor sagittal alignment and gait disturbance, suggesting that muscle degeneration could impact the biomechanical integrity of the cervical spine. Interestingly, the study found that fat infiltration was a predictor of post-surgical outcomes, particularly in relation to cervical alignment, but it did not correlate with patient-reported outcomes. This distinction is critical, as it implies that while fat infiltration may influence structural outcomes, it does not necessarily reflect the patient's perception of disability or pain.

In a more specific context, anterior cervical discectomy and fusion (ACDF) procedures were studied by Wang et al. (2022), who found that despite varying degrees of fat infiltration in the multifidus muscle, post-surgical cervical alignment remained satisfactory. Their results suggest that cervical alignment after ACDF may be resilient to muscle degeneration, at least in the short term, highlighting the complexity of surgical outcomes in patients with different levels of muscle degeneration.

Moreover, studies examining whiplash-associated disorders (WAD) also show that fat infiltration in cervical muscles correlates with poorer recovery and more severe symptoms, particularly in the first year post-injury. Elliott et al. (2020) found that patients with more severe symptoms exhibited greater fat infiltration, suggesting a link between muscle degeneration and the severity of post-traumatic symptoms, such as pain and restricted movement. These findings are supported by similar studies on chronic WAD, emphasizing that muscle changes in response to trauma may play a critical role in symptom persistence.

In patients with degenerative cervical myelopathy (DCM), Fortin et al. (2022) highlighted the relationship between muscle atrophy, fat infiltration, and muscle strength. They found that greater fat infiltration in cervical muscles was linked to poorer functional outcomes, emphasizing the role of muscle degeneration in the progression of DCM. This aligns with the findings of Li et al. (2020) in cervical spondylosis, where increased fat infiltration and misalignment were key imaging features related to worse clinical outcomes, particularly in terms of neck pain and disability (20).

The evidence across these studies suggests a complex relationship between muscle degeneration—specifically fat infiltration—and the clinical features of various neck conditions. While fat infiltration is generally associated with worse outcomes, the specific impact on function and quality of life varies depending on the underlying condition. It is clear that fat infiltration in cervical muscles reflects both structural and functional changes in the spine, which may affect both the mechanical stability of the cervical region and the patient’s ability to perform daily activities.

Future studies should focus on longitudinal assessments to clarify the causal role of fat infiltration in neck pain and disability, as well as its potential as a predictive biomarker for surgical outcomes. Additionally, the interplay between muscle degeneration, pain, and cervical spine alignment remains a topic warranting further exploration, especially as it pertains to optimizing therapeutic strategies for individuals with chronic neck conditions.

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