Cureus
Part of SPRINGER NATURE

Open Access Review Article

Multifidus Dysfunction in Chronic Low Back Pain: Pathophysiology, Patient Selection, and the Emerging Role of Restorative Neurostimulation

Review began 09/24/2026
Review ended 11/11/2026
Published 11/13/2026

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DOI: 10.7759/cureus.119614

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Abstract

Chronic low back pain is a heterogeneous condition in which impaired neuromuscular control may contribute to persistent symptoms in a subset of patients. The lumbar multifidus plays an important role in segmental spinal control, yet pain and injury can disrupt its activation and lead to changes in motor control, muscle structure, and function. Persistent multifidus dysfunction may contribute to recurrent mechanical loading and ongoing pain in a subgroup of patients, providing a rationale for therapies intended to improve multifidus activation rather than solely reduce pain. Identifying clinically relevant multifidus dysfunction requires integration of the history, physical examination, and imaging, as structural abnormalities such as atrophy or fatty infiltration do not necessarily indicate functional impairment. Restorative neurostimulation targets medial branches of the lumbar dorsal rami to generate repeated multifidus contractions, with the intended goal of improving neuromuscular control. Clinical studies have reported improvements in pain, disability, and quality of life, although the ReActiv8-B trial did not meet its prespecified 120-day primary endpoint. Longer-term follow-up suggests sustained benefits among treated participants, but controlled long-term comparisons remain limited, and restoration of multifidus function has not been directly established in the major randomized trials. Available evidence also suggests an acceptable safety profile, although implantation carries procedural and device-related risks. Important limitations remain, including the absence of a universally accepted diagnostic standard for multifidus dysfunction, reliance of long-term evidence on a limited number of cohorts, and uncertainty regarding predictors of treatment response. This narrative review examines the anatomy and function of the lumbar multifidus, its relationship with chronic low back pain, approaches to identifying dysfunction and selecting patients, the mechanism and technique of restorative neurostimulation, current clinical evidence, safety considerations, and priorities for future research.

Categories: Neurology, Pain Management, Physical Medicine & Rehabilitation
Keywords: chronic low back pain (clbp), interventional pain medicine, lumbar multifidus muscle, mechanical low back pain, multifidus atrophy, multifidus dysfunction, neuromuscular control, restorative neurostimulation, spinal stability

Introduction And Background

Low back pain (LBP) remains a major cause of disability worldwide and represents a substantial clinical and socioeconomic burden. Recent estimates from the Global Burden of Disease Study suggest that approximately 619 million people were living with LBP in 2020, with the number projected to reach 843 million by 2050 [1]. Although many acute episodes improve, LBP commonly follows a recurrent course, and a considerable proportion of patients progress to chronic LBP (CLBP) [2,3]. Once chronic, the condition can significantly impair physical function, quality of life, and participation in work and daily activities, while generating substantial healthcare utilization [4].

The management of CLBP is complicated by its clinical heterogeneity. Pain may arise through nociceptive, neuropathic, or nociplastic mechanisms, which may coexist within the same patient [5]. Similarly, several anatomical and functional contributors have been implicated, including intervertebral discs, facet joints, sacroiliac joints, vertebral endplates, spinal stenosis, and abnormalities of spinal stability and motor control [5,6]. Consequently, many patients without a clearly identifiable structural pain generator have historically been grouped under the broad designation of nonspecific CLBP. Increasing attention, however, has been directed toward identifying clinically meaningful phenotypes within this population that may permit treatment to target an underlying mechanism rather than pain symptoms alone [6].

One such phenotype involves dysfunction of the lumbar multifidus muscle. The multifidus is an important component of the deep paraspinal musculature and contributes to segmental control and dynamic

stabilization of the lumbar spine [7]. In patients with LBP, alterations in multifidus structure and function may include impaired activation, changes in motor coordination, atrophy, and fatty infiltration [7,8]. Pain or injury involving spinal structures may alter multifidus activation through inhibitory neuromuscular mechanisms, potentially contributing to impaired motor control [6,8]. Persistent dysfunction may therefore contribute to a cycle in which inadequate segmental control increases susceptibility to recurrent mechanical loading and nociceptive input, which in turn may reinforce muscle inhibition and perpetuate pain [6,8].

Recognition of this relationship has important therapeutic implications. Conventional management of CLBP includes education, exercise-based rehabilitation, pharmacologic therapy, and a range of interventional procedures. Motor control and stabilization exercises can improve pain and function in some patients, although treatment responses vary, and altered multifidus activation may persist despite rehabilitation [4,9]. This has created interest in interventions that directly address impaired multifidus activation rather than exclusively providing analgesia.

Restorative neurostimulation has emerged as a treatment approach based on the proposed role of impaired multifidus activation in CLBP, with its clinical effectiveness subsequently evaluated in prospective and randomized controlled trials. Rather than functioning primarily through sensory modulation of pain, restorative neurostimulation targets the efferent fibers of the lumbar medial branch nerve to generate repeated multifidus contractions, with the goal of progressively restoring neuromuscular control and functional spinal stability [6]. Clinical studies in carefully selected patients with refractory mechanical CLBP associated with multifidus dysfunction have reported progressive improvements in pain, disability, and health-related quality of life. Long-term follow-up of previously treated cohorts suggests sustained benefits, although randomized comparative evidence over extended periods remains limited [10]. These findings support growing interest in multifidus dysfunction as a potentially actionable contributor to CLBP while also emphasizing the importance of appropriate phenotyping and patient selection.

This narrative review examines the pathophysiological relationship between lumbar multifidus dysfunction and CLBP, with particular emphasis on altered motor control and functional spinal instability. It further reviews approaches to identifying patients with clinically relevant multifidus dysfunction, the mechanistic basis and clinical evidence for restorative neurostimulation, current limitations, and areas in which further research may help define its role within the broader management of CLBP.

Review

Literature search and selection

This narrative review draws on published literature addressing lumbar multifidus anatomy and dysfunction, CLBP, and restorative neurostimulation, including relevant clinical trials, observational studies, and review articles. Studies were selected based on their relevance to the review's objectives, with emphasis on the pathophysiology of multifidus dysfunction, patient selection, treatment outcomes, and limitations of the available evidence. No systematic search strategy, predefined eligibility criteria, or formal risk-of-bias assessment was employed; therefore, this review should not be interpreted as a systematic review or meta-analysis.

Anatomy and functional role of the lumbar multifidus

The lumbar multifidus is a deep paraspinal muscle within the transversospinalis group, located in the groove between the spinous and transverse processes of the lumbar vertebrae [11,12]. The lumbar multifidus consists of fascicles arising from the mammillary processes of the lumbar vertebrae and from attachments involving the sacrum and posterior iliac region. These fascicles extend superomedially to insert onto the spinous processes of vertebrae above their origins, spanning multiple vertebral levels [11,13]. Individual fascicles span approximately two to five vertebral levels, creating an overlapping arrangement along the lumbar spine [11].

The architecture of the multifidus varies with depth. The deeper fascicles are shorter and remain close to the vertebral column, while the more superficial fascicles are longer and cross a greater number of vertebral levels [13,14]. This arrangement has functional implications. Based on their anatomical orientation, the superficial fibers are thought to contribute more to lumbar extension and control of spinal orientation, while the shorter, deeper fibers may play a greater role in controlling movement between adjacent vertebral segments [13,14]. The relatively large cross-sectional area of the lumbar multifidus suggests a considerable capacity for force generation, although its actual contribution depends on muscle architecture, activation, and mechanical conditions [11].

The lumbar multifidus receives its motor innervation from the medial branches of the lumbar dorsal rami, with individual fascicles generally supplied in a segmental pattern [12]. This organization complements its fascicular anatomy and allows activation to be controlled across individual lumbar segments. The multifidus is also thought to contribute to proprioceptive and sensorimotor control of the lumbar spine, with its activity varying in response to posture, movement, and perturbation, although its specific proprioceptive role in CLBP remains incompletely understood [12,15]. In this way, its role extends beyond generating

movement to helping maintain controlled motion of the lumbar spine.

Although the multifidus contributes to lumbar extension, its mechanical function is more complex than that of a simple trunk extensor. Its short fascicles and close relationship to the vertebral column allow it to influence movement and loading at individual lumbar levels [13]. Based on anatomical and biomechanical analyses, Macintosh and Bogduk described posterior sagittal rotation as the principal mechanical action of the lumbar multifidus, with a smaller contribution to axial rotation. However, this mechanical interpretation does not fully capture the muscle's physiological functions during dynamic movement and spinal stabilization [13]. The multifidus also acts together with other trunk muscles to control the forces generated across the lumbar spine during movement.

Biomechanical modeling provides further support for this role. In a subject-specific musculoskeletal modeling study, Wang et al. demonstrated that altering the modeled contribution of the multifidus affected predicted compressive and shear forces across the lower lumbar spine, particularly during trunk flexion. These findings provide biomechanical insight but do not directly establish clinical outcomes in patients [11]. These modeling findings suggest that the multifidus may contribute to the regulation of segmental spinal loading, although the extent to which other paraspinal muscles, including the longissimus and iliocostalis, can compensate for altered multifidus function remains uncertain. Notably, simulated asymmetric multifidus atrophy produced only minor changes in lower lumbar compressive and shear forces during flexion [11]. This finding also cautions against using muscle size alone as a measure of multifidus function.

The anatomy of the lumbar multifidus therefore supports a role in both movement and segmental control. Its fascicular arrangement, segmental innervation, and proximity to the lumbar vertebrae allow it to contribute to the control of motion and loading across individual spinal segments [12-15]. These functions are particularly relevant when considering CLBP, in which disturbances of multifidus structure, activation, and motor control may compromise normal lumbar stabilization.

Multifidus dysfunction in CLBP

Changes in the lumbar multifidus are frequently described in patients with CLBP, although the nature and clinical significance of these changes vary between individuals. Reported abnormalities include altered muscle activation, impaired recruitment, reduced cross-sectional area, and fatty infiltration [7,8,12]. These findings have led to growing interest in the potential contribution of multifidus dysfunction to persistent mechanical LBP in a subgroup of patients, although the direction of causality remains uncertain and multifidus changes may represent both a consequence and a contributor to chronic symptoms.

One proposed mechanism begins with altered neuromuscular control following pain or injury. Nociceptive input from lumbar structures may contribute to altered neural drive and muscle activation through inhibitory neuromuscular mechanisms, although the extent to which these mechanisms explain multifidus dysfunction in CLBP remains uncertain [8]. In the lumbar spine, this may affect recruitment of the multifidus, including the timing and magnitude of its activation during movement and postural perturbation [8,15]. Experimental and clinical observations have demonstrated changes in multifidus activation in association with LBP, supporting the view that pain can modify motor control even in the absence of major structural injury [7,8].

These functional changes may persist beyond the initial painful episode. Freeman et al. described evidence that recovery of multifidus function does not necessarily occur at the same time as improvement in pain [16]. It has been hypothesized that persistent multifidus impairment may contribute to recurrent episodes of LBP through incomplete recovery of segmental motor control, although a causal relationship has not been established. However, this relationship should not be interpreted as evidence that multifidus dysfunction is responsible for all recurrent LBP or CLBP. CLBP remains heterogeneous, and multifidus dysfunction is more appropriately considered one potential mechanism within a broader range of pain phenotypes [7,12,16].

Structural changes may develop alongside altered muscle function. Multifidus atrophy and fatty infiltration have both been reported in patients with persistent LBP [7,12,16]. These changes may reflect a combination of reduced neural drive, disuse, altered loading, and longer-term muscular adaptation. Importantly, structural and functional abnormalities are not interchangeable. The presence of multifidus atrophy or fatty infiltration on imaging does not necessarily establish impaired motor control, nor does the absence of marked atrophy exclude functional dysfunction [8,12]. This distinction becomes important when attempting to identify patients in whom multifidus dysfunction is clinically relevant.

Changes in neuromuscular control may also extend beyond the muscle itself. Studies of recurrent LBP and CLBP have demonstrated altered cortical representation and motor control of the trunk musculature, suggesting that persistent pain can be accompanied by changes at several levels of the motor system [8,17]. Such changes may influence the timing and coordination of multifidus activation and provide a possible explanation for why normal recruitment is not always restored simply because pain has improved. These observations support a broader view of multifidus dysfunction as a disturbance of the neuromuscular system rather than an isolated abnormality of muscle size or strength.

The potential consequence is impaired control of lumbar motion. Because the multifidus contributes to segmental stabilization and regulation of intervertebral loading, reduced or poorly coordinated activation may compromise the ability of the muscular system to respond effectively to movement and external loads [8,11]. In susceptible patients, impaired motor control may plausibly alter spinal loading and contribute to ongoing symptoms, although the clinical causal pathway remains uncertain. Russo et al. described this as a potential cycle in which pain, impaired multifidus control, reduced functional stability, and further mechanical loading may perpetuate one another [8].

The relationship between multifidus dysfunction and CLBP is therefore likely to be bidirectional rather than a simple sequence of cause and effect. Pain can alter multifidus activation and structure, while persistent impairment of multifidus control may, in some patients, contribute to recurrent mechanical loading and continued symptoms [7,8,12,16]. This distinction is clinically important. Multifidus dysfunction should not be inferred from the presence of CLBP alone, nor from an isolated imaging abnormality. Instead, the relevant question is whether impaired multifidus function forms part of the patient's clinical pain phenotype, which provides the basis for the assessment and patient-selection strategies discussed in the following section.

Identifying multifidus dysfunction and patient selection

Multifidus dysfunction is currently identified primarily through clinical assessment. Patients typically present with chronic, predominantly axial LBP with a mechanical pattern, in which symptoms vary with posture, movement, or loading [18]. The history should establish the duration and functional impact of the pain and assess for features suggesting an alternative or competing pain generator. Particular attention should be given to radicular symptoms, neurological deficits, and structural abnormalities that may require surgical assessment. Restorative neurostimulation is intended for patients in whom impaired multifidus control is considered an important contributor to persistent symptoms [18].

Physical examination is an important part of identifying multifidus dysfunction. The prone instability test (PIT) and multifidus lift test (MLT) are commonly described for assessing functional lumbar stability and multifidus activation [18]. During the PIT, posterior-to-anterior pressure is applied over the lumbar segments first with the patient relaxed and then while the patient actively engages the trunk musculature. A reduction in provoked pain with active stabilization may suggest a component of movement-related lumbar instability or altered motor control, although the PIT has variable reliability and diagnostic accuracy and is not specific for multifidus dysfunction. The MLT provides a more direct clinical assessment of multifidus contraction during a contralateral arm-lifting maneuver [18]. These tests are not intended to establish the diagnosis independently but can strengthen the clinical impression when interpreted alongside the patient's history and other examination findings.

Imaging may complement the clinical assessment. MRI can demonstrate changes in multifidus morphology, including atrophy and fatty infiltration, and is also useful for identifying other spinal pathology that may better explain the patient's symptoms [18]. Ultrasound can provide information about multifidus morphology and changes in muscle thickness during contraction, particularly in research settings, although its clinical diagnostic utility for identifying multifidus dysfunction remains incompletely established. Importantly, structural change and functional impairment are not synonymous. Multifidus atrophy on MRI alone does not establish multifidus dysfunction and should not, in isolation, determine candidacy for restorative neurostimulation [18].

Once multifidus dysfunction has been identified, patient selection requires consideration of the broader clinical picture. The population studied in the pivotal ReActiv8-B trial consisted of adults with refractory mechanical CLBP and evidence of impaired multifidus motor control [19]. Participants had persistent symptoms despite medical management, moderate to severe pain and functional limitation, and a positive PIT. Patients whose back pain was considered amenable to surgery, as well as those with predominant leg pain, significant radiculopathy, or neurological deficits, were excluded [19]. These criteria illustrate the relatively specific clinical phenotype in which restorative neurostimulation has been most rigorously evaluated.

In practice, selection should not depend on a single examination maneuver, imaging abnormality, or measure of pain severity. Rather, history, physical examination, imaging, previous treatment response, and degree of functional impairment should be considered together [18,19]. Based on clinical trial eligibility criteria and device-specific guidance, potential candidates for restorative neurostimulation include patients with persistent mechanical axial LBP, clinical evidence suggesting impaired multifidus function, an inadequate response to conservative treatment, and no alternative pathology that more clearly explains their symptoms or warrants surgical management [18,19]. This distinction is important because restorative neurostimulation targets a functional deficit in neuromuscular control rather than the nonspecific finding of CLBP itself.

Restorative neurostimulation: mechanism and technique

Restorative neurostimulation is distinguished by its primary therapeutic aim of improving neuromuscular function through repeated muscle activation, whereas other neuromodulation approaches primarily target

pain signaling, although their underlying mechanisms may overlap. Its therapeutic target is impaired neuromuscular control of the lumbar multifidus. The proposed mechanism of restorative neurostimulation is based on the hypothesis that impaired multifidus activation may contribute to altered segmental motor control and that repeated muscle activation could facilitate improvements in neuromuscular function over time, although direct evidence confirming this mechanism remains limited [18,19]. Rather than directly stimulating the muscle, the system stimulates the motor fibers of the medial branch of the dorsal ramus, producing bilateral multifidus contractions [18].

The lumbar medial branch provides an accessible neural target because of its role in multifidus innervation. The ReActiv8 restorative neurostimulation system targets the L2 medial branch of the dorsal ramus bilaterally, with stimulation delivered where the nerve courses over the L3 transverse process [18,20]. Activation at this location recruits the multifidus through its motor nerve supply and produces a smooth contraction of the deep lumbar muscle [18]. Neural stimulation also requires less energy than attempting to stimulate the deeper multifidus fibers directly [18].

The proposed therapeutic effect develops through repeated activation rather than immediate analgesia. Electrical stimulation generates multifidus contractions despite the underlying inhibition of voluntary recruitment. Repeated contractions are intended to re-engage the neuromuscular system, with accompanying proprioceptive input contributing to recovery of motor control and functional lumbar stability [18,19]. This distinction helps explain why improvement with restorative neurostimulation may occur gradually rather than during the initial stimulation session. It also distinguishes the therapy from conventional analgesic neuromodulation, where symptom reduction itself is the principal therapeutic objective [18].

Implantation is performed using fluoroscopic guidance. Two leads are positioned bilaterally with the electrodes adjacent to the L2 medial branch nerves and connected to an implantable pulse generator [18,20]. Contemporary leads incorporate distal fixation features intended to maintain their position near the target nerve. During implantation, stimulation is used to confirm an appropriate multifidus response, with the goal of producing smooth, isolated contractions [18]. Earlier experience with restorative neurostimulation led to modification of the implantation approach after lead fractures were observed with the original technique, highlighting the importance of lead trajectory and fixation in long-term therapy [20].

Following implantation and programming, therapy is delivered intermittently rather than continuously. Patients activate the system for scheduled treatment sessions, commonly up to 30 minutes twice daily [18]. Stimulation amplitude and electrode configuration are individualized to produce comfortable multifidus contractions and can be adjusted during follow-up when necessary. This repeated, episodic activation is consistent with the restorative intent of the therapy: the objective is not continuous electrical suppression of pain, but repeated recruitment of the inhibited multifidus over an extended period [18].

A temporary stimulation trial, as commonly used before some other forms of neuromodulation, is not part of the standard ReActiv8 implantation pathway described in current clinical guidance. Because the proposed benefit develops gradually through repeated muscle activation and neuromuscular recovery, a short trial would not reproduce the expected time course of treatment [18]. Instead, appropriate clinical selection and confirmation that stimulation produces effective multifidus contraction at implantation are central to the treatment approach.

Overall, restorative neurostimulation is designed to address the functional deficit associated with multifidus dysfunction rather than treating pain in isolation. Bilateral stimulation of the L2 medial branches produces repeated multifidus contractions, providing a means of activating the muscle despite impaired voluntary recruitment [18-20]. The gradual nature of this proposed restorative process is important when interpreting the clinical evidence, particularly the progressive changes in pain and disability observed during longer-term follow-up.

Current clinical evidence

Clinical evidence for restorative neurostimulation has developed from early prospective studies to randomized trials and long-term follow-up. Initial prospective work demonstrated that repeated stimulation of the lumbar multifidus was associated with improvements in pain, disability, and quality of life in patients with refractory mechanical CLBP [20]. In the 53-patient multicenter study by Deckers et al., 58% met the predefined pain-response criterion at 90 days. The study was sponsored by Mainstay Medical Limited, the manufacturer of the ReActiv8 system. Improvements were maintained through one year, with 57% achieving a clinically important improvement in pain and 60% achieving a clinically important improvement in disability at that time point [20]. These findings provided early support for the approach but were limited by the absence of a control group.

More rigorous evidence came from the ReActiv8-B pivotal trial, a prospective, multicenter, randomized, sham-controlled study of 204 patients with refractory mechanical CLBP and evidence of multifidus motor-control impairment [19]. The trial was funded by Mainstay Medical. At the 120-day primary endpoint, 57.1%

of patients receiving therapeutic stimulation achieved at least a 30% reduction in LBP without an increase in pain medication, compared with 46.6% in the sham group (between-group difference, 10.4 percentage points; 95% CI, −3.3 to 24.1; p = 0.138). Thus, the trial did not meet its prespecified primary endpoint. However, several secondary analyses favored treatment, and after completion of the blinded phase, outcomes continued to improve as participants received therapeutic stimulation [19]. The findings suggest that clinical improvement may develop progressively over time, a pattern compatible with the proposed restorative mechanism, although the delayed response does not establish that neuromuscular restoration has occurred.

The two-year follow-up of the Mainstay Medical-funded ReActiv8-B trial showed continued improvement. At two years, 71% of participants available for follow-up reported at least a 50% reduction in LBP, while 61% achieved an improvement of at least 20 points on the Oswestry Disability Index (ODI) [21]. Overall, 76% achieved a substantial improvement in pain, disability, or both. Among participants who were taking opioids at baseline and had medication data available, 60% had voluntarily reduced or discontinued opioid use by two years [21]. Because the sham-controlled period ended at four months and all participants subsequently had access to therapeutic stimulation, these longer-term results demonstrate durability within the treated cohort but do not provide a long-term randomized comparison.

The five-year follow-up of the same Mainstay Medical-funded ReActiv8-B trial reported sustained improvements among participants with available data, although attrition and the absence of a concurrent control group limit conclusions regarding long-term comparative durability. Among participants evaluated at five years, mean pain intensity decreased from 7.3 cm at baseline to 2.4 cm on a 10 cm visual analog scale, while mean ODI improved from 39.1 to 16.5 [10]. Approximately 72% achieved at least a 50% reduction in pain, and 61% achieved an ODI improvement of at least 20 points [10]. The persistence of improvement over several years is notable because the therapy is intended to produce gradual restoration of neuromuscular function rather than temporary symptom suppression. Nevertheless, interpretation should account for attrition over prolonged follow-up and the absence of a concurrent control group after the initial blinded phase.

More recently, the RESTORE trial provided a direct comparison between restorative neurostimulation and continued optimal medical management in patients with mechanical CLBP associated with multifidus dysfunction [22]. The RESTORE trial was funded by Mainstay Medical, Inc. In this multicenter randomized trial, 203 participants were included in the analysis. At one year, mean ODI improved by 19.7 points in the restorative neurostimulation group compared with 2.9 points in the optimal medical management group (between-group difference, −16.8 points; 95% CI, −20.6 to −13.0; p < 0.001). Pain scores also improved more with restorative neurostimulation, with a mean reduction in numerical rating scale score of 3.6 points compared with 0.6 points, while health-related quality of life measured by EQ-5D-5L improved by 0.155 compared with 0.008 [22]. These findings strengthen the evidence base by demonstrating clinically meaningful differences against an active management strategy rather than relying solely on longitudinal changes from baseline.

Recent systematic reviews have further evaluated the evidence for restorative neurostimulation. Bess et al. conducted a 2025 systematic review and meta-analysis of six studies involving 650 participants, reporting improvements in pain, disability, and quality of life at one- and four-year follow-up [23]. Similarly, a 2026 meta-analysis by Bakbayeva et al., involving 15 prospective studies, reported improvements in these outcomes [24]. However, both reviews incorporated previously published clinical studies and follow-up data, including overlapping patient populations, limiting the independence of the pooled evidence. In a 2025 pooled analysis of 261 patients from ReActiv8-B, ReActiv8-C, and ReActiv8-PMCF, Ardeshiri et al. reported improvements in pain and disability among older patients at two years [25]. However, this analysis included previously studied participants and therefore does not represent an independent clinical cohort.

Additional real-world studies have provided further evidence regarding treatment outcomes. In a prospective German observational cohort of 87 patients, Amann et al. reported that more than 75% achieved at least a 30% reduction in pain and 64% achieved a clinically important improvement in disability at two years [26]. Similarly, Nowitzke et al. evaluated 50 patients in an Australian prospective observational study and reported improvements in pain, disability, trunk strength, and physical performance at one year, although these findings did not directly establish restoration of multifidus-specific function [27]. The 24-month RESTORE follow-up by Schwab et al. reported sustained improvements in pain and disability among participants originally assigned to restorative neurostimulation, with improvements also observed among those who crossed over from optimal medical management [28]. However, this report represents continued follow-up of the original RESTORE cohort [22], rather than an independent randomized trial, and the crossover design limits conclusions regarding longer-term comparative effectiveness. Several publications also share investigators, including the older-adult analysis and German observational study, as well as the RESTORE reports. Although these newer studies expand the available clinical evidence, their interpretation requires consideration of observational study designs, overlapping patient populations, shared investigators, and the absence of concurrent control groups during longer-term follow-up.

Taken together, the available evidence suggests that appropriately selected patients with refractory mechanical CLBP associated with multifidus dysfunction can experience meaningful improvements in pain,

disability, and quality of life following restorative neurostimulation [10,19,21,22]. An important feature across the longitudinal studies is that improvement tends to accumulate over time and can persist for several years. At the same time, the evidence should be interpreted within the population studied. Most trials enrolled carefully selected patients with mechanical axial LBP, evidence of multifidus dysfunction, failure of conservative treatment, and no clear indication for lumbar surgery. The results therefore should not be generalized to all patients with CLBP. Importantly, neither the ReActiv8-B nor the RESTORE trial measured multifidus function as an outcome; therefore, improvements in pain and disability cannot be taken as direct evidence that multifidus neuromuscular function was restored.

Safety, limitations, and clinical considerations

Available studies suggest that restorative neurostimulation has an acceptable safety profile in appropriately selected patients, although implantation carries risks similar to those of other implanted neurostimulation systems. Reported adverse events have included postoperative pain or discomfort, infection, lead-related complications, and device-related issues requiring revision or intervention [19,20]. In the ReActiv8-B trial, serious procedure- or device-related adverse events were uncommon, and no unanticipated serious adverse device effects were reported during the blinded phase [19]. Earlier experience also identified lead fractures associated with the initial implantation approach, which led to changes in lead design and surgical technique [20].

Longer-term follow-up has not identified a progressive safety concern associated with repeated multifidus stimulation. In the ReActiv8-B cohort, the overall safety profile remained favorable through two and five years, although some patients required surgical intervention for device- or procedure-related events [10,21]. As with any permanently implanted system, infection, lead displacement or failure, discomfort related to the implanted pulse generator, and the possibility of revision or explantation should be discussed before treatment [10,21]. These risks need to be considered against the expected benefit in a population whose symptoms have persisted despite conservative treatment.

There are also important limitations to the current evidence. Although ReActiv8-B incorporated a randomized sham-controlled phase, the blinded comparison lasted only 120 days, after which participants in the control group were allowed to receive therapeutic stimulation [19]. Consequently, the two- and five-year findings demonstrate durability among treated patients but cannot establish long-term superiority over a concurrent control group [10,21]. Attrition over several years of follow-up is another consideration, particularly when interpreting responder proportions and changes from baseline.

The RESTORE trial addressed some of these limitations by comparing restorative neurostimulation with continued optimal medical management over one year [22]. However, the nature of an implanted therapy makes long-term blinding difficult, and treatment expectations cannot be completely separated from observed outcomes. Furthermore, clinical trials have generally enrolled a relatively specific population with refractory mechanical axial LBP, evidence of multifidus dysfunction, and no clear indication for lumbar surgery [19,22]. The results should therefore not be extrapolated to the broader population of patients with CLBP, particularly those with predominant radicular pain, major neurological deficits, or another well-defined pain generator.

Another unresolved issue is how best to define clinically meaningful multifidus dysfunction. Physical examination maneuvers such as the PIT can support the diagnosis, while MRI and ultrasound may demonstrate abnormalities in muscle morphology or contraction. However, no single examination or imaging finding provides a definitive diagnosis [18]. Multifidus atrophy and fatty infiltration may accompany CLBP without necessarily establishing a functional motor-control deficit. This uncertainty makes careful clinical phenotyping particularly important and also limits direct comparison between studies that use different definitions of multifidus dysfunction.

The time course of treatment is another practical consideration. Unlike interventions intended to provide immediate analgesia, restorative neurostimulation is based on repeated activation of the multifidus and a gradual improvement in neuromuscular function [18]. Patients should therefore understand that meaningful improvement may develop over months rather than immediately after implantation. This delayed response also makes a conventional short-term stimulation trial less informative than it is for therapies in which immediate pain relief is expected [18]. Continued engagement with the prescribed stimulation schedule and appropriate follow-up are consequently important components of treatment.

Finally, the existing evidence is largely centered on a single restorative neurostimulation system and a relatively small number of clinical trials, several of which represent continued follow-up of the same patient cohort [10,19,21]. The apparent consistency of outcomes over time is encouraging, but repeated reporting from one cohort should not be interpreted as equivalent to multiple independent randomized populations. Further independent studies, broader real-world cohorts, and comparative studies against other contemporary treatments for mechanical CLBP would help clarify effectiveness across different clinical settings and refine patient selection.

Overall, restorative neurostimulation appears to offer a reasonable safety profile for carefully selected patients with refractory mechanical CLBP associated with multifidus dysfunction [10,19-22]. Its use nevertheless requires consideration of implantation-related risk, the delayed nature of the therapeutic response, diagnostic uncertainty surrounding multifidus dysfunction, and the limits of the current evidence base. These considerations are particularly important as the therapy moves from controlled clinical trials into broader clinical practice.

Future directions

Despite an expanding evidence base for restorative neurostimulation in chronic mechanical LBP associated with multifidus dysfunction, several questions remain regarding diagnosis, patient selection, treatment response, and the position of this therapy within the broader management of CLBP [10,18,19,21,22].

One important area for further study is the development of more objective methods for identifying clinically relevant multifidus dysfunction. Current assessment relies largely on the clinical history and physical examination, particularly tests such as the PIT and MLT, with MRI and ultrasound providing complementary information about muscle morphology [18]. However, multifidus atrophy or fatty infiltration on imaging does not necessarily establish functional motor impairment, and imaging findings need to be interpreted alongside the clinical assessment [18]. Future studies should therefore examine whether quantitative imaging, dynamic ultrasound, electromyography, or other measures of neuromuscular function can improve the identification and characterization of multifidus dysfunction, with particular emphasis on diagnostic reliability, inter-rater reproducibility, prediction of treatment response, and patient-important outcomes [18].

Better prediction of treatment response is another priority. The major clinical trials have enrolled a relatively specific population with persistent mechanical axial LBP, evidence of impaired multifidus control, failure of conservative management, and no indication for lumbar spine surgery [10,19,22]. It remains unclear whether characteristics such as duration of symptoms, severity of functional impairment, degree of multifidus degeneration, or previous treatment exposure influence the likelihood or magnitude of response. Identifying reliable clinical or imaging predictors could further refine patient selection and help determine which patients are most likely to benefit from implantation [18,19].

Additional independent long-term evidence is also needed. Five-year follow-up of the ReActiv8-B population demonstrated sustained improvements in pain, disability, and health-related quality of life [10]. However, much of the current long-term evidence derives from continued observation of the original ReActiv8-B cohort [10,21]. Broader prospective studies and real-world cohorts would help determine whether these outcomes are reproducible across different clinical settings and patient populations. Longer follow-up could also provide further information regarding device longevity, revision or explantation, adherence to therapy, and long-term safety [10,21].

The position of restorative neurostimulation within the treatment pathway for mechanical CLBP also requires further clarification. The RESTORE trial provides randomized comparative evidence against optimal medical management [22], while earlier studies evaluated restorative neurostimulation using sham-controlled or longitudinal designs [10,19,21]. Future comparative studies could help define how restorative neurostimulation relates to structured rehabilitation and other appropriate interventions for carefully selected patients with mechanical CLBP. Outcomes should extend beyond pain intensity and disability to include physical activity, return to work, medication use, health-related quality of life, healthcare utilization, and cost-effectiveness [10,21,22].

Further investigation of the biological effects of restorative neurostimulation may also improve understanding of its mechanism. The therapy is intended to repeatedly activate the inhibited multifidus and facilitate restoration of neuromuscular control rather than directly suppress pain signaling [18]. The progressive and durable clinical improvements reported in longitudinal studies are consistent with a restorative process, but clinical improvement alone does not establish that neuromuscular function has been restored [10,21]. Future studies incorporating serial measurements of multifidus activation, muscle morphology, motor control, and functional spinal stability could help determine whether objective changes in multifidus function accompany clinical improvement and whether these changes predict treatment response [10,18,21].

Overall, future research should focus on establishing more consistent diagnostic criteria for multifidus dysfunction, identifying predictors of treatment response, expanding independent long-term and real-world evidence, and defining the role of restorative neurostimulation relative to other treatments for mechanical CLBP [10,18,19,21,22]. A better understanding of the relationship between multifidus dysfunction, restoration of neuromuscular control, and clinical improvement may ultimately allow treatment to be directed more precisely toward the patients most likely to benefit.

Conclusions

Multifidus dysfunction may represent a clinically relevant component of chronic mechanical LBP in a

selected group of patients. Its contribution extends beyond muscle atrophy, involving altered activation, impaired motor control, and disruption of segmental spinal stability. Recognizing this phenotype requires a clinical assessment that considers symptoms, physical examination findings, imaging, and alternative pain generators rather than relying on any single diagnostic finding. Restorative neurostimulation offers a mechanism-based approach by repeatedly activating the lumbar multifidus with the aim of restoring neuromuscular control. Clinical studies have reported improvements in pain and function in appropriately selected patients. However, the ReActiv8-B trial did not meet its prespecified 120-day primary endpoint, and longer-term findings are based on uncontrolled follow-up of treated cohorts, limiting conclusions regarding comparative durability. Furthermore, neither ReActiv8-B nor RESTORE measured multifidus function as an outcome, leaving the proposed restoration of neuromuscular control unconfirmed by these trials. Important questions remain regarding diagnosis, prediction of treatment response, and generalizability beyond studied populations. Further independent and comparative research should clarify these uncertainties and define the therapy's place within CLBP management. Ultimately, better identification of clinically relevant multifidus dysfunction may help guide patient selection for treatments targeting impaired neuromuscular function, although further research is needed to establish the relationship between improvements in multifidus function and clinical outcomes.

Additional Information

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All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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