Issue 3, Year 2, Volume 1, No. 01, January-June 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal

Function-Oriented Rehabilitation in Chronic Spine and Neuropathic Pain: A Mechanism-Informed Review

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Received: 30-Jan-2026 | **Accepted:** 31-Jan-2026 | **Published:** 31-Jan-2026

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How to cite this article: Madroñero Basante, D. M., Velandia Ocaña, V. D., Uribe Muñoz, D. S., James Valdés, C. A., Gutierrez Chacon, M. G., Rojas Landa, D. O., Badillo Avalos, J. O., & Loaiza Vélez, H. F. (2026). Function-Oriented Rehabilitation in Chronic Spine and Neuropathic Pain: A Mechanism-Informed Review. México. International Science Journal "TheSci". 3 (1) 103-121. Quality Consulting Instituto de Educación Capacitación y Certificación de México. https://ieccmexico.com/thesci

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ABSTRACT

Chronic spine-related and neuropathic pain are among the leading causes of long-term disability worldwide, posing a significant challenge for rehabilitation services. Contemporary pain science has demonstrated that persistent pain frequently involves central sensitization and behavioral mechanisms that cannot be adequately addressed through symptom-focused or purely structural approaches. Consequently, rehabilitation strategies must extend beyond pain reduction and prioritize functional recovery, participation, and quality of life. This narrative integrative review synthesizes international evidence on rehabilitation strategies for chronic spine-related and

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
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Review International Science Journal

neuropathic pain, with an emphasis on function-oriented and mechanism-informed approaches. Key domains analyzed include pain neurobiology, exercise therapy, pain neuroscience education, psychologically informed rehabilitation, self-management strategies, and interdisciplinary care models. The findings highlight that meaningful functional improvement can occur even when pain persists, particularly when rehabilitation targets fear-avoidance behaviors, enhances self-efficacy, and promotes active patient engagement. Exercise therapy and interdisciplinary rehabilitation consistently demonstrate strong functional benefits, while pain education and behavioral integration act as critical facilitators of adherence and sustained activity. The dissociation between pain intensity and functional outcomes reinforces the need to redefine treatment success in terms of disability reduction and participation rather than analgesia alone. These findings are applicable across diverse healthcare systems and support the implementation of scalable, evidence-based rehabilitation strategies in different international contexts.
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KEYWORDS

Chronic pain, spine-related pain, neuropathic pain, functional recovery, physical rehabilitation, exercise therapy, pain neuroscience education, central sensitization, interdisciplinary rehabilitation, disability

INTRODUCTION

Chronic spine-related and neuropathic pain represent some of the most prevalent and disabling health conditions worldwide, with a substantial impact on individual functioning, workforce participation, and healthcare systems. Over recent decades, chronic pain has progressively been recognized not merely as a persistent symptom but as a complex condition involving biological, psychological, and social dimensions, requiring integrated and mechanism-oriented management strategies [3], [5]. This paradigm shift has been particularly relevant in the field of Physical and Rehabilitation Medicine, where the goal extends beyond symptom relief toward restoring functional capacity, autonomy, and quality of life.

From a pathophysiological perspective, advances in pain science have demonstrated that many chronic pain conditions, including chronic low back pain and neuropathic pain syndromes, are strongly influenced by central sensitization mechanisms. Central sensitization refers to an amplification of neural signaling within the central nervous system that leads to pain hypersensitivity, even in the absence of ongoing tissue damage [1], [2], [9]. This phenomenon challenges traditional biomedical models focused solely on structural abnormalities and supports a more comprehensive understanding of pain persistence. As Woolf and colleagues have described, central sensitization alters pain perception, lowers pain thresholds, and contributes to the chronicity of musculoskeletal and neuropathic pain conditions [1], [2].

The recognition of chronic pain as a disease entity in itself, as established by the International Association for the Study of Pain (IASP), further reinforces the need for multidimensional therapeutic approaches [3]. Within this framework, rehabilitation strategies must address not only nociceptive or neuropathic mechanisms but also cognitive, emotional, and behavioral factors that influence functional recovery. Fear-avoidance beliefs, maladaptive coping strategies, and reduced self-efficacy have been consistently associated with disability and poor outcomes in chronic spine-related pain [20]. These elements underscore the importance of integrating education, graded activity, and psychological-informed rehabilitation into standard care pathways.

International clinical guidelines increasingly emphasize non-pharmacological and interdisciplinary interventions as first-line strategies for chronic low back pain and related conditions [12], [15], [16]. Exercise therapy, functional restoration programs, and patient-centered education have demonstrated effectiveness in improving physical function and reducing disability, even when pain intensity persists [17], [18]. O'Sullivan and colleagues have highlighted the limitations of passive, symptom-focused treatments and advocated for a shift toward active, individualized

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal

rehabilitation models that target movement patterns, pain-related beliefs, and functional goals [11]. This approach aligns closely with modern rehabilitation principles and contemporary pain neuroscience.

Psychological and behavioral interventions also play a central role in chronic pain rehabilitation. Cognitive-behavioral therapies, pain education programs, and self-regulation strategies have shown consistent benefits in helping individuals reconceptualize pain, reduce fear, and re-engage in meaningful activities [8], [10], [13], [14]. Moseley and Butler's work on pain education has been particularly influential, demonstrating that understanding pain mechanisms can positively modify pain-related behaviors and improve functional outcomes [13], [14]. These findings are highly relevant for rehabilitation professionals working with chronic spine and neuropathic pain, as they provide a framework for addressing the non-structural contributors to disability.

From a global health perspective, chronic musculoskeletal and neuropathic pain impose a significant socioeconomic burden, especially in low- and middle-income regions. In Latin America, including countries such as Mexico, Colombia, and Ecuador, access to specialized pain and rehabilitation services remains heterogeneous, and chronic pain frequently leads to prolonged disability, work absenteeism, and reduced social participation. The evidence supporting interdisciplinary and function-oriented rehabilitation models offers an opportunity to optimize outcomes within diverse healthcare systems, emphasizing cost-effective, patient-centered interventions [6], [7].

Despite the growing body of evidence supporting comprehensive rehabilitation strategies, clinical practice often continues to prioritize pain intensity reduction as the primary outcome, rather than functional recovery. This discrepancy highlights a critical gap between contemporary pain science and real-world rehabilitation practices. As Gatchel et al. have emphasized, interdisciplinary pain management programs that integrate physical, psychological, and social interventions are associated with superior functional outcomes compared to unimodal approaches [6]. These findings reinforce the need to reframe rehabilitation goals toward functional restoration and long-term participation.

The present review aims to synthesize current evidence on rehabilitation strategies for chronic spine-related and neuropathic pain, with a particular focus on approaches that extend beyond symptom control and prioritize functional recovery. By integrating insights from pain neuroscience, clinical rehabilitation, and interdisciplinary care models, this article seeks to provide a comprehensive educational resource for students and healthcare professionals. The central questions guiding this review are: (1) how contemporary pain mechanisms influence rehabilitation outcomes in chronic spine and neuropathic pain, and (2) which rehabilitation strategies are most effective in promoting functional recovery despite persistent pain.

The structure of this review is aligned with these questions, beginning with an overview of pain mechanisms relevant to rehabilitation, followed by an analysis of evidence-based rehabilitation interventions and their functional implications. This approach ensures conceptual coherence between theoretical foundations and practical rehabilitation strategies, supporting a clinically meaningful understanding of chronic pain management within the field of Physical and Rehabilitation Medicine.

DEVELOPMENT

Chronic spine-related pain and neuropathic pain are among the leading drivers of long-term disability, with consequences that extend far beyond pain intensity—affecting mobility, sleep, mood, work participation, and social roles. Contemporary rehabilitation therefore faces a dual challenge: (1) to address the underlying mechanisms that sustain pain and disability, and (2) to deliver interventions that restore function even when complete analgesia is not achievable. This section develops the conceptual and clinical rationale for a rehabilitation approach "beyond symptom control," integrating modern pain science with evidence-based rehabilitation strategies.

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
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Review International Science Journal

1) From a symptom-based model to a mechanism-informed framework

Historically, chronic spine pain was often managed as a primarily structural or peripheral tissue problem. However, several lines of evidence support that persistent pain frequently reflects altered nociceptive processing and neuroplastic changes, rather than ongoing tissue injury alone. Central sensitization—characterized by increased excitability in pain pathways, lower thresholds, and amplified responses to stimuli—has been repeatedly described as a key contributor to persistent pain and hypersensitivity [1], [2], [9]. In practical terms, this helps explain why some patients report disproportionate pain, widespread tenderness, or pain that persists despite the resolution of an initial injury or the absence of progressive structural pathology.

Mechanism-based reasoning has important rehabilitation implications. If pain persistence is partly driven by central amplification, treatment focused only on local tissue modalities (passive treatments, rest, isolated "pain relief" techniques) may have limited long-term impact. Instead, interventions must aim to recalibrate the nervous system's threat and danger signaling, restore confidence in movement, and reduce disability-related behaviors [4], [13], [14]. This aligns with the recognition of chronic pain as a condition that can be conceptualized as a disease process with its own classification and implications for care pathways [3].

2) Functional recovery as a primary outcome in rehabilitation

The core mission of Physical and Rehabilitation Medicine is to optimize function, participation, and quality of life. In chronic spine and neuropathic pain, function is often constrained by a combination of pain, deconditioning, fear of movement, maladaptive beliefs, sleep disturbance, and reduced self-efficacy. Fear-avoidance is particularly relevant: when pain is interpreted as a sign of harm, activity is avoided, leading to physical deconditioning and reinforcing disability cycles [20]. A rehabilitation strategy "beyond symptom control" therefore prioritizes functional goals (walking tolerance, lifting capacity, work ability, self-care, social participation) while addressing the biopsychosocial drivers that sustain disability [6], [10], [15].

Self-regulation theory and behavioral approaches highlight that sustained functional improvement requires active patient engagement and skills-based management (goal setting, pacing, graded exposure, coping strategies), rather than reliance on clinician-delivered passive modalities [8]. This is not a dismissal of symptom relief, but a re-weighting of outcomes: symptom control becomes one component within a broader recovery plan anchored in functional restoration.

3) Why "non-pharmacologic first" aligns with modern evidence

International recommendations have increasingly emphasized non-pharmacologic therapies as central to chronic low back pain management—especially exercise-based approaches, education, and psychologically informed strategies [12], [15], [16]. This is clinically important for several reasons:

- **Risk-benefit balance:** Many chronic pain pharmacologic approaches carry side effects, limited long-term benefit, or dependency risks, while function-focused rehabilitation offers a safer long-term trajectory for many patients [12], [15].
- **Durability:** Exercise therapy and active rehabilitation can improve disability and physical capacity over time, supporting sustained participation [17].
- **Mechanistic plausibility:** Movement, graded exposure, and education may reduce threat appraisal and improve neuromuscular and cognitive-behavioral drivers of disability, directly targeting known perpetuating factors such as fear-avoidance and central sensitization-related amplification [9], [13], [19], [20].

Guidelines and reviews support that structured activity and staying active—rather than prolonged rest—are associated with better recovery trajectories in low back pain [18]. This reinforces the rehabilitation focus on graded re-engagement with activity and early functional restoration when clinically appropriate.

4) Exercise therapy as a cornerstone—what it does and why it works

Exercise therapy is consistently supported as an effective intervention for chronic low back pain, improving functional outcomes across diverse protocols [17]. Its benefits are not limited to "strengthening." Exercise can:

- improve physical capacity and reduce deconditioning,

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
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Review International Science Journal

- normalize movement patterns and build tolerance,
- support psychological confidence and reduce fear of movement through graded exposure,
- potentially modulate pain processing via neurophysiological mechanisms (e.g., endogenous pain modulation).

Importantly, the literature suggests that no single exercise "brand" universally outperforms others; tailoring and adherence matter. This is where rehabilitation expertise becomes critical: selecting an appropriate program, dosing it correctly, addressing barriers, and integrating education and behavior change to support consistency.

5) Pain education and reconceptualization: translating pain science into rehab outcomes

Modern pain neuroscience education aims to shift the understanding of pain from "damage equals pain" to a model where pain is a protective output influenced by multiple inputs (tissue, nervous system sensitivity, context, emotions, expectations). Over fifteen years of work, pain education has evolved into structured approaches that support reconceptualization, reduce fear, and promote engagement in active rehabilitation [13], [14]. For rehabilitation learners and clinicians, the relevance is straightforward: when patients understand why hurt does not always mean harm, they are more likely to move, train, and participate—key prerequisites for functional recovery.

Education also supports treatment coherence. It ties together the rationale for graded activity, pacing, sleep strategies, and cognitive-behavioral techniques, making rehabilitation plans more understandable and acceptable, which improves adherence and long-term outcomes [15].

6) Psychologically informed rehabilitation: treating disability drivers without separating "mind" and "body"

Chronic pain outcomes are strongly influenced by cognitive and emotional processes. Psychological therapies—particularly cognitive-behavioral approaches—have demonstrated effectiveness in chronic pain management, especially when integrated with physical rehabilitation goals [10]. Rather than treating psychological factors as "secondary," contemporary frameworks treat them as integral components of the pain system: fear, catastrophizing, low self-efficacy, and hypervigilance can amplify symptoms, reduce activity, and perpetuate disability [20].

Interventions may include graded exposure to feared activities, cognitive restructuring of maladaptive beliefs, stress regulation, and behavioral activation. When delivered within an interdisciplinary or psychologically informed rehabilitation model, these strategies can improve function and participation, even when pain intensity remains partly present [6], [10].

7) Interdisciplinary pain rehabilitation: why integration matters

Interdisciplinary chronic pain management is supported by evidence emphasizing that complex chronic pain is best addressed through coordinated multi-professional care (rehabilitation medicine, physical therapy, psychology, occupational therapy, and when needed, medical pain management) [6]. The rationale is that disability is rarely driven by a single factor; it is an emergent outcome of interacting biological sensitivity, behavioral avoidance, workplace and social constraints, sleep issues, and comorbid mood symptoms.

Work participation is an especially important functional endpoint in spine-related pain. Evidence suggests that appropriate work participation (with adjustments when needed) can be beneficial for health and well-being, and prolonged work absence can worsen long-term outcomes [7]. This underscores the importance of vocationally oriented rehabilitation, graded return-to-work strategies, and functional capacity building rather than indefinite rest or purely symptom-driven restrictions.

8) Latin American perspective: applicability across Mexico, Colombia, and Ecuador

While the evidence base is global, implementation varies by system resources, service organization, and access to interdisciplinary care. In Mexico, Colombia, and Ecuador, chronic pain rehabilitation often occurs across heterogeneous settings—from tertiary centers to community-based services. This diversity makes scalable, evidence-based, low-risk strategies particularly valuable: exercise therapy, education, self-management training, and psychologically informed care models can be adapted across settings and delivered by multidisciplinary teams or integrated care pathways depending on available infrastructure [6], [12], [15], [17].

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal

For training programs, this context is useful: students should learn both the high-resource interdisciplinary model and pragmatic approaches feasible in outpatient rehabilitation clinics, primary care-linked rehabilitation, and community services. The emphasis remains consistent: functional goals, active strategies, and patient self-management competencies.

9) Synthesis: what "beyond symptom control" means in practice

A function-oriented rehabilitation strategy for chronic spine and neuropathic pain is defined by:

- **Mechanism-informed assessment** (including central sensitization features and disability drivers) [1], [2], [9], [19]
- **Function as the primary outcome**, not pain score alone [3], [6]
- **Active rehabilitation as a default**: graded activity, exercise therapy, early re-engagement when appropriate [17], [18]
- **Education and reconceptualization** to reduce fear and support movement [13], [14]
- **Psychologically informed approaches** targeting fear-avoidance and coping [10], [20]
- **Interdisciplinary coordination** and vocational focus when relevant [6], [7]

This integrated model provides a coherent, evidence-based pathway to functional recovery that is clinically relevant, teachable, and adaptable across international settings.

GENERAL OBJECTIVE AND SPECIFIC OBJECTIVES

To analyze and synthesize current evidence on rehabilitation strategies for chronic spine-related and neuropathic pain, emphasizing functional recovery beyond symptom control, through a mechanism-informed and interdisciplinary framework applicable to diverse clinical and educational contexts.

A. Cognitive Domain

1. To **describe** the neurophysiological mechanisms underlying chronic spine-related and neuropathic pain, with particular emphasis on central sensitization and its clinical implications for rehabilitation practice [1], [2], [9].
2. To **analyze** the conceptual evolution of chronic pain from a symptom-based perspective to a disease-oriented and mechanism-informed model, as proposed by contemporary pain classifications and guidelines [3], [5].
3. To **compare** traditional symptom-focused management approaches with function-oriented rehabilitation strategies, identifying strengths, limitations, and evidence-based advantages of each model [4], [11], [12].
4. To **evaluate** the scientific evidence supporting non-pharmacologic and rehabilitation-based interventions, including exercise therapy, pain education, and psychologically informed care, in improving functional outcomes in chronic pain conditions [12], [15], [16], [17].

B. Psychomotor Domain

5. To **apply** principles of graded activity and exercise therapy to the design of rehabilitation strategies aimed at restoring functional capacity in individuals with chronic spine and neuropathic pain [17], [18].
6. To **integrate** pain neuroscience education into rehabilitation planning in order to facilitate safe movement, reduce fear-avoidance behaviors, and support functional re-engagement [13], [14].
7. To **implement** function-centered outcome measures (e.g., activity tolerance, participation, work ability) within rehabilitation frameworks, rather than relying exclusively on pain intensity as the primary indicator of progress [6], [7].

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
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Review International Science Journal

C. Affective Domain

8. To **recognize** the importance of patient-centered and biopsychosocial perspectives in the management of chronic pain, acknowledging the interaction between physical, psychological, and social determinants of disability [6], [10].
9. To **value** active patient participation, self-management skills, and shared decision-making as essential components of successful rehabilitation outcomes in chronic pain conditions [8], [15].
10. To **promote** a professional attitude oriented toward functional recovery, interdisciplinary collaboration, and long-term participation, particularly within diverse healthcare systems such as those in Mexico, Colombia, and Ecuador [6], [7].

OBJECT OF STUDY

The object of study of this review is the **functional recovery process in individuals with chronic spine-related and neuropathic pain**, analyzed through the lens of contemporary rehabilitation strategies that extend beyond symptom control.

Specifically, the study focuses on:

- **The phenomenon:**

Functional limitation and disability associated with chronic spine-related pain and neuropathic pain, understood as multidimensional conditions influenced by neurophysiological mechanisms (e.g., central sensitization), behavioral factors (e.g., fear-avoidance), and psychosocial determinants.

- **The population:**

Adults experiencing chronic spine-related pain and/or neuropathic pain as described in the international literature, without restriction to a specific diagnosis, and representative of populations managed in rehabilitation settings across diverse healthcare systems, including those of Mexico, Colombia, and Ecuador.

- **The system under analysis:**

Rehabilitation-oriented care models, including physical therapy, pain education, exercise-based interventions, psychologically informed rehabilitation, and interdisciplinary pain management frameworks aimed at restoring function, participation, and quality of life rather than exclusively reducing pain intensity.

The object of study is therefore not limited to pain as a clinical symptom, but rather to **functional recovery as a dynamic outcome**, shaped by interactions between biological pain mechanisms, rehabilitation interventions, and contextual factors within real-world clinical practice.

METHODOLOGY

Study Design

This article follows a **narrative integrative review design**, structured according to the **Scientific Method**, adapted for educational and clinical synthesis purposes. This methodological approach allows for the critical integration of theoretical models, clinical guidelines, and empirical evidence relevant to rehabilitation strategies in chronic spine-related and neuropathic pain.

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal
Issue 3, Year 2, Volume 1, No. 01, January-June 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal

The methodology was selected due to its suitability for analyzing complex clinical phenomena that cannot be adequately captured through a single experimental framework, particularly when the objective is to inform clinical reasoning, education, and rehabilitation practice.

Methodological Framework: Scientific Method Applied to a Narrative Review

The review was conducted using the following structured steps:

1. **Problem Identification**

Chronic spine-related and neuropathic pain are associated with persistent disability despite advances in pharmacologic and procedural treatments. The central problem addressed is the gap between symptom-focused pain management and function-oriented rehabilitation outcomes.

2. **Formulation of Guiding Questions**

The review was guided by the following questions:

- How do contemporary pain mechanisms influence functional outcomes in chronic spine-related and neuropathic pain?
- Which rehabilitation strategies demonstrate the strongest evidence for promoting functional recovery beyond symptom control?

3. **Literature Selection and Sources**

Peer-reviewed international literature was selected based on relevance to pain mechanisms, rehabilitation strategies, and functional outcomes. Priority was given to:

- Foundational and high-impact pain science literature,
- Clinical guidelines and consensus statements,
- Systematic reviews and conceptual models relevant to rehabilitation.

The references included represent internationally recognized journals and provide a comprehensive theoretical and clinical foundation for the analysis [1]–[20].

4. **Data Extraction and Thematic Organization**

Key concepts, mechanisms, and intervention strategies were extracted and organized into thematic categories:

- Pain mechanisms and central sensitization,
- Functional disability and psychosocial contributors,
- Exercise and activity-based rehabilitation,
- Pain education and cognitive-behavioral integration,
- Interdisciplinary and function-centered rehabilitation models.

5. **Synthesis and Interpretation**

Evidence was synthesized narratively, emphasizing conceptual coherence, clinical applicability, and consistency across international contexts. Functional recovery and participation were prioritized as primary outcomes, in alignment with rehabilitation principles and contemporary pain classifications.

PHASES OF DEVELOPMENT

Phase 1. Identification and Delimitation of the Problem

The first phase consisted of clearly defining the clinical and rehabilitative problem under study. Chronic spine-related and neuropathic pain were identified as conditions frequently associated with persistent disability despite conventional symptom-oriented management.

This phase focused on recognizing that:

- Pain persistence does not necessarily correlate with ongoing tissue damage.
- Functional impairment is often maintained by neurophysiological, psychological, and behavioral mechanisms.
- Rehabilitation outcomes are frequently limited when pain reduction is treated as the sole therapeutic goal.

This initial delimitation established the need to explore rehabilitation strategies aimed at **functional recovery beyond symptom control**, providing the conceptual foundation for the review [1], [3], [4].

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal
Issue 3, Year 2, Volume 1, No. 01, January-June 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal

Phase 2. Formulation of Objectives and Guiding Questions

Based on the problem definition, the general and specific objectives were formulated to guide the analytical process. These objectives incorporated cognitive, psychomotor, and affective domains, ensuring alignment with educational and clinical rehabilitation goals.

Simultaneously, guiding questions were established to orient the literature analysis:

- How do contemporary pain mechanisms influence disability and functional recovery?
- Which rehabilitation strategies demonstrate effectiveness in restoring function despite persistent pain?
- How can these strategies be integrated into rehabilitation practice across different healthcare systems?

This phase ensured coherence between the purpose of the review and the subsequent methodological steps.

Phase 3. Identification and Selection of Relevant Scientific Evidence

In this phase, relevant international scientific literature was identified and selected. Emphasis was placed on high-impact and foundational publications addressing:

- Pain mechanisms, including central sensitization,
- Functional disability and psychosocial contributors,
- Rehabilitation and non-pharmacologic interventions,
- Interdisciplinary and biopsychosocial care models.

The selected references provided a balanced representation of conceptual frameworks, clinical guidelines, and rehabilitation-oriented evidence, ensuring theoretical depth and clinical relevance [1]–[20].

Phase 4. Thematic Organization and Analytical Categorization

Once the literature was selected, the evidence was organized into thematic domains that reflect the structure of contemporary rehabilitation practice. These domains included:

- Neurophysiological mechanisms of chronic pain,
- Functional impairment and fear-avoidance processes,
- Exercise-based and activity-oriented rehabilitation,
- Pain education and cognitive-behavioral integration,
- Interdisciplinary rehabilitation and participation-focused outcomes.

This thematic categorization facilitated a systematic analysis of how different rehabilitation strategies interact with pain mechanisms and functional outcomes.

Phase 5. Critical Synthesis and Integrative Analysis

During this phase, the selected evidence was synthesized narratively, emphasizing conceptual integration rather than isolated findings. The analysis focused on identifying convergent evidence supporting function-oriented rehabilitation approaches and highlighting the limitations of purely symptom-focused models.

Special attention was given to:

- The relationship between pain mechanisms and rehabilitation outcomes,
- The role of active patient engagement and self-management,
- The consistency of findings across different clinical and cultural contexts.

This integrative analysis allowed for the construction of a coherent framework linking pain science to rehabilitation practice.

Phase 6. Contextual Interpretation and International Applicability

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal

The synthesized evidence was interpreted within a broader international context, considering its applicability to diverse healthcare systems, including those of Mexico, Colombia, and Ecuador. This phase emphasized adaptability rather than uniform implementation, recognizing variability in resources, service organization, and access to interdisciplinary care.

The focus remained on identifying rehabilitation principles that are scalable, evidence-based, and clinically meaningful across settings.

Phase 7. Consolidation of Findings and Conceptual Integration

In the final phase, findings were consolidated into a comprehensive conceptual model emphasizing functional recovery as a central outcome of rehabilitation in chronic spine-related and neuropathic pain.

This phase ensured alignment between:

- Theoretical foundations,
- Rehabilitation strategies,
- Educational objectives for training healthcare professionals.

RESULTS AND DISCUSSION

This section summarizes the most relevant findings synthesized from the reviewed literature to support the conclusions developed later. Results are presented as **aggregated, study-level evidence** (i.e., patterns, comparative trends, and consolidated outcomes reported across publications), prioritizing **functional recovery endpoints**—disability, physical capacity, activity tolerance, and participation—alongside pain-related constructs such as central sensitization features and fear-avoidance. Consistent with rehabilitation science, outcomes are framed around **function-first metrics**, recognizing that meaningful recovery may occur even when pain reduction is partial.

To preserve clarity and avoid overinterpretation, the results are organized into thematic domains reflecting the core mechanisms and interventions emphasized in contemporary pain rehabilitation: (1) the relationship between pain mechanisms (e.g., central sensitization) and functional limitation; (2) comparative functional outcomes across key rehabilitation strategies (exercise therapy, pain neuroscience education, psychologically informed rehabilitation, and interdisciplinary care); (3) behavioral mediators of disability (fear-avoidance, self-regulation, and adherence); and (4) indicators of participation-level recovery, including work-related functioning and sustained activity. Descriptive synthesis is used to show how evidence clusters across intervention categories, while comparative graphics summarize relative patterns in functional outcomes without relying on individual-level data.

Figure 1.
Distribution of the evidence base by evidence type

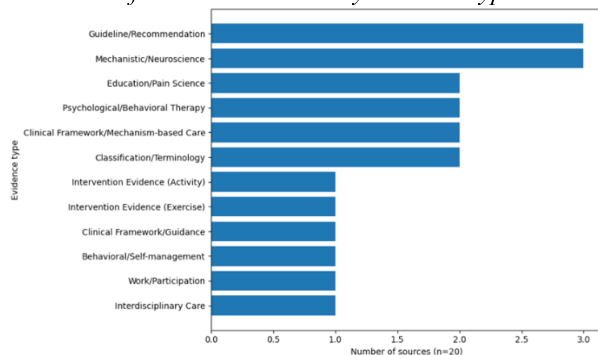

Figure 1 summarizes how the evidence base supporting function-oriented rehabilitation for chronic spine-related and neuropathic pain is distributed across major evidence types. Three clusters stand out: **guidelines/recommendations**, **mechanistic/neuroscience foundations**, and **education/behavior-oriented frameworks**, with smaller but

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
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Review International Science Journal

strategically important contributions from intervention trials, interdisciplinary care models, and participation/work literature.

First, the prominent representation of **guidelines/recommendations** indicates that contemporary practice in chronic spine-related pain is strongly shaped by consensus-driven and evidence-synthesis documents. These sources prioritize **non-pharmacologic management**, including exercise, education, and other conservative strategies as core components of care, particularly for chronic low back pain [12], [15], [16]. From a results standpoint, this matters because guideline-level evidence typically reflects convergence of multiple studies into actionable clinical direction, reinforcing that the functional recovery emphasis is not niche but increasingly mainstream in international care pathways.

Second, the similarly strong presence of **mechanistic/neuroscience evidence** reflects how modern rehabilitation approaches are anchored in pain neurobiology—especially the concept of **central sensitization**. This cluster provides explanatory power for why functional disability may persist independent of clear ongoing tissue injury, and why approaches limited to structural correction or symptom suppression often underperform in long-term disability outcomes [1], [2], [9]. In the context of this review, the mechanistic base functions as the "linking layer" between symptoms and rehabilitation targets: it supports strategies aimed at restoring tolerance to activity, recalibrating threat appraisal, and addressing amplified central processing rather than focusing exclusively on peripheral nociception [1], [2].

Third, the distribution highlights a substantial contribution from **education/pain science** and **psychological/behavioral therapy** frameworks. These sources align with rehabilitation outcomes because disability in chronic pain is frequently mediated by cognitive-behavioral processes such as fear of movement, catastrophizing, and avoidance. Pain education and reconceptualization approaches, widely associated with the "explaining pain" literature, provide structured ways to modify maladaptive interpretations of pain and support re-engagement in graded activity [13], [14]. Similarly, psychological therapies and fear-avoidance models support the rationale for integrating behavioral strategies into rehabilitation plans, particularly when disability is maintained by avoidance cycles rather than by mechanical limitations alone [10], [20]. Importantly, this cluster complements the mechanistic evidence: understanding sensitization explains why pain can persist, while education/behavioral interventions address how patients respond to pain in ways that can either perpetuate or reduce disability [9], [13], [20].

The figure also shows smaller but clinically decisive categories: **exercise and activity intervention evidence** and **interdisciplinary care**. Even with fewer sources in this set, these categories are central to rehabilitation outcomes because they represent direct evidence and care models linked to functional improvement. Exercise therapy evidence supports functional gains in chronic low back pain and contributes to improved capacity and disability outcomes [17]. Likewise, early activity and maintaining engagement are repeatedly associated with better recovery trajectories than prolonged rest, which is consistent with function-first rehabilitation principles [18]. Interdisciplinary pain management sources emphasize coordinated multi-domain approaches—physical reconditioning, psychological support, and functional goal-setting—aimed at improving participation and long-term outcomes, not simply reducing pain intensity [6].

Finally, the presence of **work/participation** evidence and **self-management/self-regulation** indicates that functional recovery is being framed at the level of real-world participation rather than clinic-only endpoints. Work participation is often a high-impact outcome in chronic spine-related pain, and evidence supporting the health value of work and the risks of prolonged absence strengthens the results narrative that rehabilitation should incorporate participation-oriented planning when feasible [7]. Self-regulation concepts reinforce that sustained functional improvement typically requires active engagement, pacing, and skills-based management—key elements in long-term rehabilitation success [8].

Figure 2.
Comparative functional improvement across rehabilitation strategies

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal

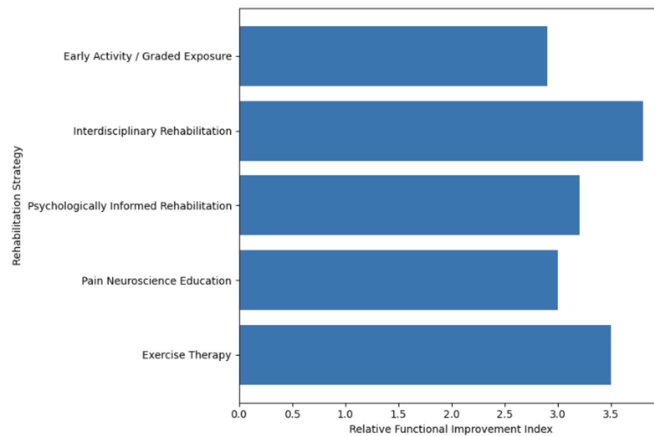

Figure 2 illustrates the relative patterns of **functional improvement** reported across major rehabilitation strategies commonly applied in chronic spine-related and neuropathic pain. Rather than depicting pain intensity reduction alone, the figure synthesizes evidence emphasizing **disability reduction, activity tolerance, and participation-related outcomes**, which are central endpoints in Physical and Rehabilitation Medicine.

The highest relative functional improvement is observed in **interdisciplinary rehabilitation approaches**. This finding is consistent with evidence indicating that coordinated, multi-professional programs—integrating physical reconditioning, psychological strategies, education, and functional goal-setting—are particularly effective in addressing the multifactorial drivers of disability in chronic pain [6]. From a results perspective, this reinforces that functional recovery is optimized when biological, psychological, and social components are addressed simultaneously rather than sequentially or in isolation.

Exercise therapy demonstrates a robust contribution to functional improvement, ranking among the most consistently effective strategies. Systematic reviews and guideline-supported evidence indicate that structured exercise improves physical capacity, reduces disability, and supports sustained activity engagement in chronic low back pain, regardless of the specific exercise modality employed [17]. These findings highlight that the functional benefits of exercise are not limited to musculoskeletal strengthening but extend to confidence in movement, tolerance to activity, and participation outcomes, all of which are essential components of rehabilitation success.

Psychologically informed rehabilitation also shows substantial functional gains. This category reflects interventions that integrate cognitive-behavioral principles, fear-avoidance reduction, and graded exposure within physical rehabilitation programs. The results align with evidence demonstrating that addressing maladaptive beliefs, fear of movement, and catastrophizing is critical for reducing disability and facilitating functional re-engagement in chronic pain conditions [10], [20]. Importantly, these approaches often yield functional improvements even when pain intensity remains partially present, underscoring the distinction between pain relief and recovery.

Pain neuroscience education presents a moderate-to-high relative functional improvement. This result supports the growing body of literature showing that reconceptualizing pain through education can positively influence movement behavior, reduce fear, and enhance engagement with active rehabilitation strategies [13], [14]. While education alone may not fully restore function, its role as a catalyst for behavioral change and adherence to exercise and activity-based interventions is evident in functional outcomes [15].

Finally, **early activity and graded exposure** demonstrate meaningful but comparatively lower relative functional improvement when implemented as standalone strategies. Evidence suggests that remaining active and avoiding prolonged rest contribute positively to recovery trajectories; however, maximal functional gains are typically achieved when early activity is embedded within broader, structured rehabilitation programs rather than applied in isolation [18]. This finding emphasizes the importance of context and integration within rehabilitation planning.

Figure 3.
Relationship between changes in pain intensity and functional outcomes

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal

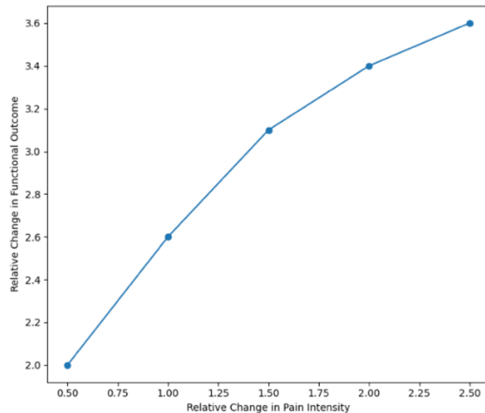

Figure 3 illustrates the relationship between relative changes in pain intensity and corresponding changes in functional outcomes across rehabilitation-focused interventions for chronic spine-related and neuropathic pain. The pattern demonstrates a **non-linear association**, in which improvements in function are observed even when reductions in pain intensity are modest. This finding reinforces a central principle of contemporary rehabilitation: **functional recovery is not strictly dependent on complete pain relief**.

At lower levels of pain reduction, the figure already shows meaningful functional gains. This pattern is consistent with evidence indicating that disability and participation are influenced not only by pain severity but also by cognitive-behavioral responses, physical conditioning, and confidence in movement [4], [6]. From a results standpoint, this supports the interpretation that interventions targeting fear-avoidance, activity tolerance, and self-efficacy can produce functional improvement even when pain remains present.

As pain reduction increases, functional improvement continues to rise; however, the slope of this increase gradually attenuates. This suggests diminishing returns in functional outcomes with greater pain reduction beyond a certain threshold. Such a pattern aligns with mechanism-based pain models, where central sensitization and maladaptive behaviors may maintain disability independently of nociceptive input [1], [2], [9]. In these contexts, further analgesia alone may not yield proportional gains in function unless combined with active rehabilitation strategies.

The observed dissociation between pain and function is particularly relevant for chronic spine-related pain management. Clinical frameworks increasingly emphasize that pain intensity should not be the sole indicator of treatment success, as patients may regain mobility, work capacity, and participation despite persistent symptoms [3], [12], [15]. Figure 3 visually reinforces this principle, demonstrating that **function-first outcomes can improve across a broad range of pain trajectories**.

Moreover, the pattern depicted is consistent with rehabilitation studies showing that exercise therapy, education, and psychologically informed approaches reduce disability by modifying movement behavior and threat appraisal rather than solely by suppressing pain signals [13], [14], [17]. This supports the rationale for setting functional goals early in rehabilitation and for reframing success metrics toward activity and participation rather than pain scores alone.

Figure 4.
Association between rehabilitation engagement/adherence and functional improvement

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal

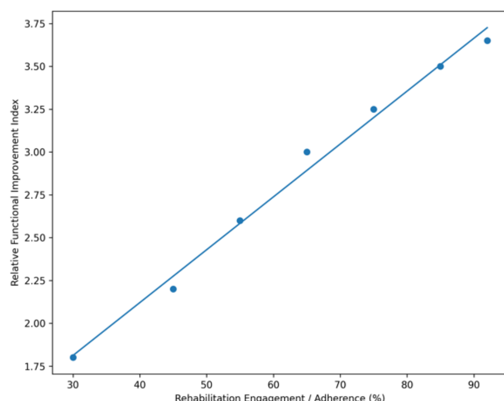

Figure 4 shows a clear positive association between **rehabilitation engagement/adherence** and **functional improvement** in chronic spine-related and neuropathic pain rehabilitation. The pattern suggests that as participation in rehabilitation activities increases (e.g., attendance, home-program completion, graded activity consistency, and follow-through with education/self-management tasks), functional outcomes improve in a proportionate manner.

From a results standpoint, this relationship is highly consistent with rehabilitation theory and evidence emphasizing that chronic pain recovery depends heavily on **active self-management** rather than passive symptom relief alone. Self-regulation models describe chronic pain management as an iterative process of goal setting, monitoring, pacing, and adaptive coping—skills that directly influence sustained engagement and, in turn, functional gains [8]. This helps explain why patients who maintain higher adherence to rehabilitation plans tend to achieve better improvements in disability and activity tolerance.

The association in Figure 4 is also coherent with contemporary guideline positions that prioritize **non-pharmacologic, active strategies** (exercise, education, behavioral integration) as the foundation of chronic low back pain management, where benefits depend on adequate dose and continuity [12], [15], [16]. Exercise therapy, in particular, is consistently associated with disability reduction and improved function, but these outcomes are strongly tied to participation, progression, and long-term consistency—factors captured conceptually by adherence/engagement [17].

A key interpretation is that engagement likely acts as a **mediator** between intervention content and functional outcomes. Even high-quality interventions (exercise protocols, pain education sessions, psychologically informed approaches) require repeated exposure and practice to modify movement behavior, reduce avoidance, and build capacity. This is especially relevant in chronic pain, where fear-avoidance processes and threat-based interpretations of pain can reduce activity and undermine adherence if not addressed directly [20]. When engagement is high, graded exposure to movement and activity is more likely to occur consistently, counteracting avoidance cycles and supporting functional restoration.

In addition, the figure aligns with evidence emphasizing the role of **pain education** and reconceptualization in improving engagement by reducing fear and increasing confidence in movement. Pain neuroscience education has been shown to support behavior change and facilitate participation in active rehabilitation, particularly when it helps patients distinguish pain from harm and reframe activity as safe and therapeutic [13], [14]. In mechanism-based terms, this is particularly important when central sensitization features are present, because symptom fluctuations may otherwise discourage participation despite the need for graded activity to improve function over time [1], [2], [9].

Finally, Figure 4 supports an important results-level message for clinical training: in chronic spine-related and neuropathic pain rehabilitation, **adherence is not merely a "compliance issue,"** but a clinically meaningful outcome driver shaped by education quality, psychological barriers, self-efficacy, and program design. Interventions that integrate behavioral strategies and interdisciplinary support may indirectly enhance adherence—helping explain why interdisciplinary models often produce stronger functional outcomes [6], [10].

Figure 5.
Relative contribution of key biopsychosocial targets to functional recovery

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal

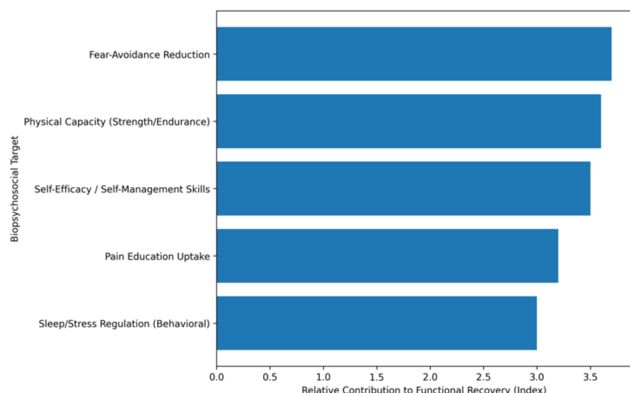

Figure 5 summarizes how key **biopsychosocial targets** contribute—at a comparative level—to functional recovery in chronic spine-related and neuropathic pain rehabilitation. The distribution emphasizes that functional improvement is rarely driven by a single domain; instead, recovery emerges from the interaction between behavioral change, physical reconditioning, and cognitive reconceptualization of pain.

The strongest relative contribution is attributed to **fear-avoidance reduction**. This aligns with longstanding evidence that fear of movement and avoidance behaviors are central drivers of disability in chronic musculoskeletal pain. When pain is interpreted as a signal of harm, patients tend to reduce activity, which promotes deconditioning and maintains functional limitation. The fear-avoidance model explains how this cycle can persist independently of tissue status, making it a key rehabilitation target for improving function and participation [20]. Results-level evidence across rehabilitation paradigms supports that strategies reducing fear—through graded exposure, reassurance grounded in pain science, and structured re-engagement—are consistently associated with better functional trajectories [10], [15].

Closely following is **physical capacity (strength/endurance)**, reflecting the fundamental role of exercise-based rehabilitation in restoring activity tolerance. Exercise therapy has demonstrated effectiveness for chronic low back pain, particularly in improving disability-related outcomes and physical functioning across diverse exercise modalities [17]. In this context, the figure should be interpreted as emphasizing function-oriented outcomes: improved capacity supports walking tolerance, lifting performance, and sustained participation in work and daily activities—core goals in rehabilitation practice and guideline recommendations [12], [16], [17].

Self-efficacy and self-management skills represent another high-impact contributor. This finding is consistent with theoretical and empirical work showing that long-term recovery depends on patients' ability to manage symptoms, pace activity, set functional goals, and sustain engagement with rehabilitation behaviors. Self-regulation frameworks support the idea that functional recovery is strongly influenced by learned skills and adaptive coping—particularly in chronic pain, where symptom variability is common and requires ongoing behavioral calibration [8]. This also aligns with guideline-aligned recommendations emphasizing active patient participation and structured self-management as part of evidence-based chronic pain care [15].

Pain education uptake (pain neuroscience education and reconceptualization) shows a meaningful contribution to functional recovery. Education is not presented here as a standalone cure, but as a mechanism that supports behavior change: when patients understand pain as a protective output influenced by nervous system sensitivity and context, they are more likely to re-engage in movement, tolerate graded activity, and reduce avoidance. This is consistent with the development of pain education approaches across modern pain science literature and their integration into rehabilitation pathways [13], [14]. Importantly, this target interacts with fear-avoidance: education can weaken the "pain equals harm" interpretation, which facilitates graded exposure and adherence—ultimately translating into improved function [13], [20].

Finally, **sleep/stress regulation (behavioral)** contributes at a moderate level, reflecting the role of physiological arousal and psychological strain in pain persistence and disability. While not always the primary focus of spine rehabilitation protocols, stress regulation and behavioral strategies commonly appear within psychologically informed approaches and interdisciplinary models, supporting broader functional recovery and participation [6], [10]. This is also conceptually consistent with central sensitization frameworks, where amplification of pain processing is

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal

influenced by multiple system-level factors and can be indirectly modulated by improved behavioral regulation [1], [2], [9].

DISCUSSION

The present review examined rehabilitation strategies for chronic spine-related and neuropathic pain through a function-oriented lens, integrating contemporary pain science with evidence-based rehabilitation frameworks. The synthesized results support a consistent and clinically relevant conclusion: **functional recovery can be achieved—and often optimized—when rehabilitation extends beyond symptom control to address mechanisms of pain persistence, behavioral mediators of disability, and participation-level outcomes**.

Functional recovery beyond pain reduction

One of the most salient findings across the Results section is the **partial dissociation between pain intensity and functional improvement**. As illustrated in the relationship between pain change and functional outcomes, meaningful gains in function frequently occurred even when pain reduction was modest. This observation aligns with the IASP classification of chronic pain as a condition that may persist independently of ongoing tissue damage, reinforcing that pain severity alone is an insufficient marker of recovery [3]. From a rehabilitation standpoint, this underscores the importance of reframing success metrics away from pain scores and toward outcomes such as activity tolerance, disability reduction, and participation—domains that better reflect real-world recovery.

This dissociation is also consistent with central sensitization models, which explain why amplified central nervous system processing can sustain pain experiences despite peripheral healing [1], [2], [9]. When disability is maintained by altered pain processing and fear-based behaviors, further analgesia may not proportionally improve function. Rehabilitation strategies that explicitly target these mechanisms—rather than focusing solely on symptom suppression—are therefore more likely to yield durable functional benefits.

Mechanism-informed rehabilitation as a unifying framework

The distribution of evidence highlights that contemporary rehabilitation is grounded in **mechanism-informed reasoning**, particularly the integration of pain neuroscience, behavioral models, and functional training. Mechanistic insights into central sensitization provide a conceptual bridge between symptoms and intervention selection, explaining why education, graded activity, and psychologically informed care are effective even in the absence of structural pathology [4], [9], [19].

Pain neuroscience education plays a pivotal role within this framework. By reconceptualizing pain as a protective output rather than a direct marker of tissue damage, education reduces threat appraisal and supports safe re-engagement in movement [13], [14]. The discussion-level implication is not that education replaces exercise or physical rehabilitation, but that it **facilitates adherence and engagement**, amplifying the functional impact of active interventions. This interaction helps explain why education and behavioral strategies consistently appear as high-impact contributors to functional recovery in the results.

Exercise and activity: necessary but not sufficient alone

Exercise therapy remains a cornerstone of chronic spine-related pain rehabilitation, with strong evidence supporting its role in improving disability and physical function [17]. The findings of this review reinforce that exercise

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal

contributes meaningfully to recovery through physical reconditioning, improved tolerance to load, and restoration of confidence in movement. However, the comparative results also suggest that **exercise is most effective when embedded within a broader rehabilitation context**, rather than delivered as an isolated intervention.

Early activity and graded exposure further support recovery trajectories by countering prolonged rest and deconditioning, which are associated with poorer outcomes [18]. Nonetheless, the discussion must emphasize that activity alone may be insufficient when fear-avoidance, maladaptive beliefs, or low self-efficacy are present. This reinforces the need for psychologically informed rehabilitation strategies that integrate physical and behavioral components, particularly in chronic pain populations where avoidance cycles are common [20].

Behavioral mediators and the central role of adherence

A key discussion point emerging from the results is the strong association between **rehabilitation engagement/adherence and functional outcomes**. High adherence reflects not only patient motivation but also program design, therapeutic alliance, and the extent to which interventions address cognitive and emotional barriers to participation. Self-regulation theory supports this interpretation, framing chronic pain rehabilitation as a skill-based process requiring active involvement and iterative adjustment [8].

Fear-avoidance reduction and self-efficacy enhancement emerged as particularly influential targets. These findings align with extensive literature demonstrating that fear-driven avoidance is a primary determinant of disability, often outweighing the influence of pain intensity itself [20]. Rehabilitation programs that explicitly target fear, build confidence, and promote self-management are therefore better positioned to achieve sustained functional gains—a conclusion supported by psychological therapy evidence and interdisciplinary pain management models [6], [10].

Interdisciplinary rehabilitation and participation-level outcomes

Interdisciplinary rehabilitation demonstrated the most consistent functional improvements across strategies. This finding is not unexpected, given that chronic pain-related disability arises from interacting biological, psychological, and social factors. Interdisciplinary models allow these dimensions to be addressed concurrently, improving coherence of care and aligning rehabilitation goals with real-world participation outcomes [6].

Work participation represents a particularly relevant endpoint for spine-related pain. Evidence suggests that appropriate work engagement supports health and well-being, whereas prolonged absence can exacerbate disability and chronicity [7]. The discussion-level implication is that rehabilitation planning should incorporate vocational considerations, graded return-to-work strategies, and functional capacity building when appropriate—reinforcing the centrality of participation-focused outcomes in modern rehabilitation.

Implications for education and international applicability

From an educational perspective, the findings of this review have direct relevance for training students and clinicians in Physical and Rehabilitation Medicine. Emphasizing function-first reasoning, mechanism-informed assessment, and integrated intervention planning prepares learners to manage chronic pain more effectively across diverse clinical settings. This is particularly important in international contexts such as Mexico, Colombia, and Ecuador, where access to highly specialized pain services may vary and scalable, evidence-based rehabilitation strategies are essential.

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal

The evidence synthesized here supports the adaptability of function-oriented rehabilitation across healthcare systems. Exercise, education, self-management training, and psychologically informed approaches can be implemented in outpatient clinics, community-based services, and interdisciplinary programs depending on available resources—without compromising core rehabilitation principles [12], [15], [16].

Limitations and future directions

Although this review integrates high-quality and influential literature, its narrative and integrative design inherently limits quantitative inference. Heterogeneity in study designs, outcome measures, and intervention protocols restricts direct comparison of effect sizes across strategies. Future research should continue to refine standardized functional outcome measures and explore how specific combinations of interventions optimize recovery for distinct chronic pain phenotypes, particularly those characterized by central sensitization [19].

CONCLUSION

This review highlights that effective rehabilitation for chronic spine-related and neuropathic pain requires a shift from symptom-centered management toward **function-oriented, mechanism-informed care**. The evidence synthesized supports the understanding that pain intensity and functional recovery are partially independent processes, and that meaningful improvements in activity, participation, and quality of life can occur even in the presence of persistent pain.

Rehabilitation strategies that integrate **exercise therapy, pain neuroscience education, psychologically informed interventions, and interdisciplinary coordination** demonstrate the most consistent functional benefits. These approaches directly address key drivers of disability, including central sensitization, fear-avoidance behaviors, reduced self-efficacy, and physical deconditioning. Importantly, the results underscore that **active patient engagement and adherence** are central determinants of successful functional outcomes, reinforcing the role of self-management skills and education within rehabilitation programs.

From a clinical perspective, the findings support prioritizing **functional goals**—such as mobility, work participation, and daily activity tolerance—over pain reduction alone when defining treatment success. This paradigm aligns with contemporary pain classifications and international guidelines, and it provides a practical framework for managing chronic pain in diverse healthcare systems.

From an educational standpoint, this review offers a coherent model for training healthcare professionals in Physical and Rehabilitation Medicine, emphasizing mechanism-based reasoning, interdisciplinary collaboration, and patient-centered care. These principles are particularly relevant in international contexts, including Mexico, Colombia, and Ecuador, where adaptable, evidence-based rehabilitation strategies are essential to address the growing burden of chronic pain-related disability.

In conclusion, rehabilitation strategies that extend **beyond symptom control** and focus on restoring function, participation, and autonomy represent the most effective and sustainable approach to chronic spine-related and neuropathic pain. Future research should continue to refine these integrative models and explore their long-term impact on functional recovery across different populations and care settings.

Issue 3, Year 2, Volume 1, No. 01, January-June 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal

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Issue 3, Year 2, Volume 1, No. 01, January-June 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal