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NEUROMATRIX-INFORMED PHYSIOTHERAPY FOR CHRONIC PAIN MANAGEMENT: A SCOPING REVIEW OF EVIDENCE AND CLINICAL APPLICATIONS

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ABSTRACT

Background: Pain is a complex, multifaceted experience that extends beyond mere nociception. The neuromatrix theory, introduced by Melzack, reframes our understanding of pain by conceptualizing it as an output of a widely distributed neural network influenced by sensory input, cognitive evaluation, and emotional state. **Aim:** This scoping review examined the application of the neuromatrix model within physiotherapy, evaluating its relevance as a comprehensive, non-pharmacological framework for managing diverse pain conditions.
Methods: A systematic search was conducted between January 15 to january 30 2025, across PubMed, Science Direct, and Google Scholar using predefined keywords. After screening 1,273 articles and assessing 127 full-text papers, 36 studies met the inclusion criteria, including randomized controlled trials, observational studies, qualitative research, and mixed-methods designs. The review mapped how physiotherapists apply neuromatrix-informed strategies-such as movement therapy, pain neuroscience education, manual techniques, and psychosocial interventions-to address the multidimensional nature of pain.
Results: Findings underscore a shift from biomedical to biopsychosocial approaches, highlighting the importance of therapeutic alliance, patient beliefs, and neuroplasticity in modulating pain perception and promoting recovery. Interventions targeting chronic pain conditions such as low back pain, fibromyalgia, and phantom limb pain showed evidence of altered brain activity and pain modulation consistent with neuromatrix principles.
Results: However, study heterogeneity and limited high-quality trials suggest that further research is needed to confirm these outcomes and support broad implementation.

Keywords; Neuromatrix theory, chronic pain, physiotherapy, biopsychosocial model, non-pharmacological interventions.

ABBREVIATIONS

Al	Artificial Intelligence
AR	Augmented Reality
CBT	Cognitive Behavioral Therapy
CLBP	Chronic Low Back Pain
FMRI	Functional Magnetic Resonance Imaging
GMI	Graded Motor Imagery
RCT	Randomized Controlled Trial
VR	Virtual Reality

INTRODUCTION

Pain as a pandemic refers to the global prevalence of chronic and severe pain conditions that significantly impact individual health, societal function, and healthcare systems[1]. This concept underscores the notion that pain is not an isolated symptom, but a multidimensional disease affecting physical, psychological, and social well-being[2]. It is a leading cause of disability worldwide, particularly among working-age adults and older populations, contributing to increased morbidity, healthcare utilization, and economic burden[3]. Chronic pain affects over 1.5 billion people globally[4], with conditions such as back pain, osteoarthritis, neuropathy, and fibromyalgia documented in virtually every country[5].

Beyond physical suffering, chronic pain disrupts employment, education, mental health, and social participation[6]. A significant disparity exists in access to pain management, particularly in low- and middle-income countries, where the availability of effective therapies and pain medications is limited. Unlike acute pain, chronic pain may persist for months or even years, becoming a lifelong condition for many[7]. Despite its widespread impact, chronic pain is often underdiagnosed and undertreated—reflecting systemic gaps in medical education, healthcare delivery, and research priorities.

The Neuromatrix Theory of Pain was developed to address limitations of earlier models, such as the biomedical and gate control theories[8], which could not adequately explain persistent or complex pain phenomena. Ronald Melzack proposed the neuromatrix theory based on clinical observations that pain could continue in the absence of active tissue damage, vary greatly between individuals, or even be felt in body parts that no longer exist—such as in phantom limb pain. These insights emphasized the need for a more inclusive framework that considers the brain, emotions, memory, cognition, and genetics in the pain experience.

According to the neuromatrix theory, pain is not simply a direct response to sensory signals but an output generated by a neural network in the brain—the neuromatrix—that integrates multiple sources of input, including sensory, emotional, and cognitive signals[9]. This theory helps explain why individuals with similar injuries report vastly different pain experiences and why chronic pain may persist long after healing has occurred. A key example supporting this theory is phantom limb pain, in which individuals experience pain in an amputated limb[10], reinforcing the concept that pain is brain-derived and not solely tissue-based.

In clinical practice, the neuromatrix model aligns closely with the biopsychosocial approach to pain, promoting a holistic framework for assessment and intervention. This model legitimizes the subjective pain experiences of patients and supports treatment strategies that engage both the body and mind[11]. Interventions such as cognitive-behavioral therapy, mindfulness-based practices, and neuroplasticity-driven rehabilitation target the brain's processing of pain and offer promise in reducing pain-related disability[12].

THE ROLE OF PHYSIOTHERAPY IN PAIN MANAGEMENT

Physiotherapy plays a pivotal role in the management of pain, particularly in the context of chronic pain conditions. It offers a holistic approach that integrates physical, emotional, and psychological elements, in alignment with the neuromatrix theory[13]. Physiotherapists utilize a range of techniques, including manual therapy, exercise therapy, and education, to address the underlying causes of pain, improve function, and reduce disability. Furthermore, physiotherapy aims to empower individuals to manage their pain through self-care strategies, improving their quality of life. As chronic pain continues to rise globally, physiotherapy has emerged as a cornerstone in the treatment and rehabilitation of individuals affected by this condition[14].

Objectives Of The Review

This scoping review aims to explore the intersection between the pain pandemic, the neuromatrix theory of pain, and the role of physiotherapy in addressing chronic pain. The objectives of this review are to:

- Examine the global prevalence and impact of chronic pain, contributing to the pain pandemic.
- Analyze the neuromatrix theory of pain as a comprehensive framework for understanding chronic pain conditions.
- Explore the evidence for physiotherapy interventions in the management of chronic pain and their alignment with the neuromatrix theory.
- Identify the challenges and future directions of neuromatrix-based physiotherapy in pain management

MATERIALS AND METHODS

Search Strategy

Databases: PubMed, Science Direct, Google Scholar

Search period: January 15–30, 2025

Date Range: January 2000–December 2024

Search Terms: “neuromatrix” OR “pain matrix” AND “physiotherapy” OR “physical therapy” AND “chronic pain” OR “persistent pain” AND “biopsychosocial” OR “holistic”

Time Frame: The search covered articles published from January 2000 to December 2024, aligning with the exclusion criterion that omitted studies older than the year 2000.

Eligibility Criteria

Inclusion Criteria: Studies were eligible for inclusion if they met the following criteria:

i. Addressed the application of the Neuromatrix Theory within physiotherapy practices.

ii. Focused on chronic pain and rehabilitation in a physiotherapy context.

iii. Included human participants (with musculoskeletal, neurological, or chronic pain conditions).

iv. Published as peer-reviewed journal articles, including both qualitative and quantitative designs between 2000 – 2024.

Exclusion Criteria:

The following were excluded:

i. Non-peer-reviewed publications.
ii. Studies involving solely theoretical frameworks or animal models.
iii. Articles not focused on physiotherapy or clinical applications of the Neuromatrix Theory.
iv. Publications prior to the year 2000.

Study Selection Process

The selection followed the PRISMA-ScR framework:

1. Identification: A total of 1,273 articles were identified across the selected databases.

2. Screening: After removing 218 duplicates, 1,055 articles were screened by title and abstract.

3. Eligibility: 127 full-text articles were retrieved and assessed for relevance.

4. Inclusion: 36 studies met all inclusion criteria and were included in the final review.

Data Extraction and Synthesis

Data from the included studies were charted into categories including study type, population, intervention type, and key findings. No formal risk of bias assessment or quality grading was performed, as is consistent with scoping review methodology. Instead, a descriptive synthesis was conducted to map current evidence and identify gaps related to neuromatrix-informed physiotherapy for chronic pain.

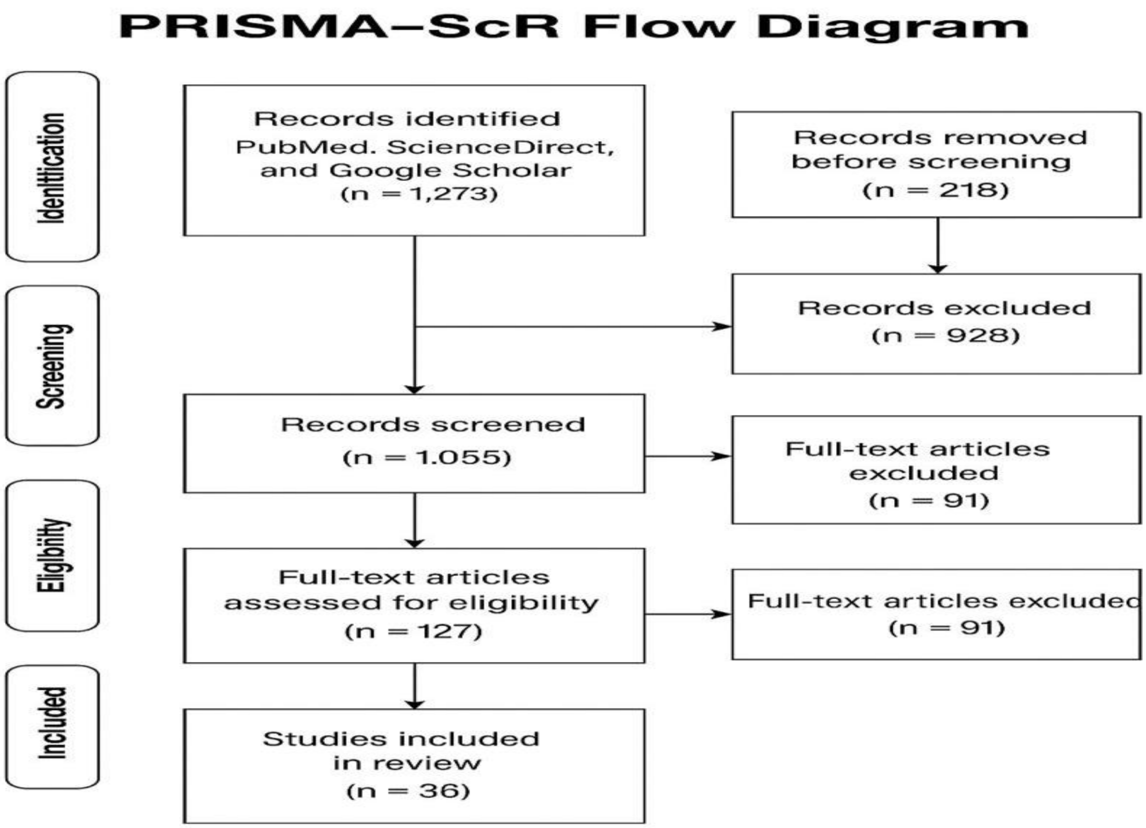

FIGURE 1: PRISMA Flow Diagram

RESULT

Study Selection

The initial database search yielded 1,273 articles. Following the removal of 218 duplicates, 1,055 records were screened by title and abstract. Of these, 127 full-text articles were assessed for eligibility, and 36 studies met the final inclusion criteria. The study selection process is detailed in the PRISMA-ScR flow diagram (Figure 1).

Characteristics of Included Studies:

Among the 36 included studies:

i. 15 were randomized controlled trials (RCTs)
ii. 10 were observational studies
iii. 6 were qualitative studies
iv. 5 employed mixed-methods designs

Populations Studied

The studies addressed various chronic pain populations:

i. Chronic low back pain (n = 18)
ii. Fibromyalgia (n = 9)
iii. Chronic neck pain (n = 5)
iv. Other chronic pain conditions (n = 4), including neuropathic pain and generalized musculoskeletal pain

Intervention Types

The interventions evaluated across the studies included:

i. Pain neuroscience education (n = 20).
ii. Graded motor imagery (n = 12)
iii. Biopsychosocial-based exercise programs (n = 18)
iv. Mindfulness-based physiotherapy (n = 6)

Key Findings

Most of the studies reported positive outcomes in areas such as:

i. Pain reduction
ii. Improved physical function
iii. Enhanced patient engagement and self-efficacy

Interventions informed by the Neuromatrix Theory often emphasized cognitive-emotional factors, neuroplasticity, and the importance of therapeutic alliance. However, there was variation in intervention protocols, duration, and outcome measures, which limited the ability to generalize across populations and settings.

ANALYZING NEUROMATRIX THEORY IN PAIN MANAGEMENT

The Neuromatrix Theory of pain, proposed by Ronald Melzack in the late 20th century, revolutionized the understanding of chronic pain[15]. Unlike previous models, which focused solely on the idea of pain being a direct result of tissue damage, the neuromatrix theory introduces a more complex and multidimensional view. It suggests that pain is not merely a response to sensory input, but rather a result of the brain's processing of multiple factors such as sensory, emotional, and cognitive inputs. This integrated process occurs within a neural network known as the "neuromatrix" in the brain, which is responsible for the perception of pain, as well as other phenomena such as body image and emotion[16].

The theory emphasizes that pain perception is constructed by the brain based on both incoming stimuli and pre-existing neural patterns[17]. It highlights the role of the brain's plasticity, suggesting that the brain's pain networks can be shaped by experiences, emotions, and prior pain experiences, thus offering a more comprehensive explanation for chronic pain conditions.

Cognitive, Emotional, and Sensory Factors in Chronic Pain

Melzack's neuromatrix theory integrates several factors in the experience of chronic pain:

Cognitive Factors: Thoughts, beliefs, expectations, and past experiences can profoundly influence how a person experiences pain[18]. For example, fear-avoidance models show that individuals who catastrophize about pain or expect worse outcomes are likely to experience heightened pain intensity and disability. Cognitive-Behavioral therapy (CBT) is often used to address these factors in the treatment of chronic pain.

Emotional Factors: Emotions such as stress, anxiety, depression, and fear are known to amplify the perception of pain. Emotional distress can enhance pain sensitivity by altering neural processing in the brain[18]. Chronic pain can also lead to emotional dysregulation, creating a vicious cycle that worsens the pain experience[19].

Sensory Factors: These are the traditional, physiological aspects of pain, such as tissue injury or inflammation[20]. However, sensory input alone is insufficient to explain the full experience of pain, which is where the cognitive and emotional factors come in. For instance, people with chronic pain often report heightened sensitivity to stimuli that would not normally be painful[21].

STUDIES SUPPORTING THE NEUROMATRIX MODEL

Fibromyalgia: A condition marked by widespread musculoskeletal pain, fibromyalgia has been associated with heightened central sensitization and abnormal sensory processing in the brain. Studies using functional magnetic resonance imaging (fMRI) have shown that individuals with fibromyalgia exhibit altered brain activity in regions linked to pain processing, such as the insula, anterior cingulate cortex, and thalamus, aligning with the neuromatrix model[22].

Phantom Limb Pain: Research on phantom limb pain, where individuals experience sensations in a limb that no longer exists, provides strong evidence for the neuromatrix theory. The pain is not caused by any tissue injury but rather the brain's processing of the missing limb's sensory input. Studies suggest that reorganization of the sensory cortex in the brain leads to the experience of pain, even in the absence of sensory input from the limb[23].

Chronic Back Pain: Chronic low back pain (CLBP) is another example where the neuromatrix model has been supported. Studies have shown that emotional and cognitive factors significantly influence the intensity and persistence of back pain[24]. Furthermore, fMRI studies demonstrate altered brain activity in people with chronic back pain, including changes in the primary somatosensory cortex, which suggests a shift in how sensory input is processed[25].

PHYSIOTHERAPY INTERVENTIONS FOR CHRONIC PAIN: ALIGNING WITH THE NEUROMATRIX THEORY

Physiotherapy encompasses a wide range of treatment approaches designed to alleviate pain, restore function, and improve quality of life for individuals experiencing chronic pain. These approaches are not one-size-fits-all but are tailored to meet the unique needs of each patient. The key physiotherapy methods that have gained attention in the context of chronic pain include:

Manual Therapy:
Manual therapy techniques, such as joint mobilization and soft tissue manipulation, are commonly used to reduce pain and improve mobility[26]. The hands-on approach aims to restore normal joint function, alleviate muscular tension, and reduce mechanical nociceptive (pain-producing) signals[27]. These methods are particularly useful in musculoskeletal pain syndromes like lower back pain, neck pain, and joint arthritis.

Movement-Based Interventions:
Movement therapies, including exercise-based rehabilitation, focus on restoring proper movement patterns and improving physical conditioning[28]. These may include therapeutic exercises, postural training, and functional movement retraining. Movement-based interventions help improve strength, flexibility, and endurance, which not only reduce pain but also promote long-term recovery and prevent future injuries. Exercise has been found to have both physical and psychological benefits, helping individuals with chronic pain improve their mood, self-efficacy, and overall well-being[29].

Neuroplasticity Techniques:
Neuromuscular re-education and techniques aimed at stimulating the brain's neuroplasticity play an important role in pain management[30]. These techniques are designed to retrain the brain and nervous system to re-establish normal pain processing patterns, ultimately reducing pain perception. Approaches like graded motor imagery (GMI) or sensory discrimination training target the brain's cortical representation of the affected body part[31]. These techniques can effectively address central sensitization, a phenomenon in which the brain's pain processing becomes amplified and distorted, leading to chronic pain[32]. Physiotherapy approaches are inherently aligned with the Neuromatrix Theory, as they focus on the multifactorial aspects of pain, integrating both the physical and cognitive-emotional dimensions. The neuromatrix framework suggests that pain is not just a sensory experience but is also influenced by psychological and social factors. Physiotherapy incorporates this holistic view by targeting both the physical manifestations of pain and addressing the psychological barriers to recovery[33].
Manual therapy and movement-based interventions help modulate sensory inputs to the brain, potentially reshaping how pain is perceived and processed. By improving joint function and movement, these interventions directly influence the sensory components of pain, while also contributing to the brain's neuroplastic changes, thus supporting the brain's ability to recalibrate its pain response. Neuroplasticity techniques are directly aligned with the neuromatrix model. By engaging the brain's ability to adapt and reorganize itself, physiotherapists leverage neuroplasticity to alter pain processing patterns[34]. This approach helps break the cycle of chronic pain by retraining the brain's response to stimuli, ultimately reducing pain perception and improving motor function.

Moreover, physiotherapists often educate patients about pain neuroscience, helping them understand the role of the brain in pain perception. This education empowers patients to actively engage in their recovery and reduces fear-avoidant behaviors, which are common in chronic pain conditions and further perpetuate the pain cycle.

PATIENT-CENTERED APPROACHES AND BIOPSYCHOSOCIAL APPLICATIONS

A patient-centered approach is fundamental in contemporary physiotherapy practice, particularly when treating chronic pain. This approach recognizes that pain is a complex experience influenced by physical, emotional, and social factors[35].

Biopsychosocial Model: The biopsychosocial model of pain integrates biological, psychological, and social elements into the treatment plan[36]. In physiotherapy, this means recognizing the importance of not only the physical symptoms of pain (such as musculoskeletal dysfunction) but also the emotional and social contexts that influence pain perception and coping[37]. By addressing the psychological impact of pain, such as anxiety, depression, or fear of movement, physiotherapists can help break the vicious cycle that exacerbates chronic pain.

Psychosocial Support: Many physiotherapists incorporate techniques like cognitive-behavioral therapy (CBT) or mindfulness-based approaches to help patients manage the emotional and cognitive aspects of pain[38]. These techniques teach patients to recognize and challenge unhelpful thoughts and beliefs about pain, thus improving their emotional well-being and reducing pain intensity. For example, by promoting a positive outlook, reducing catastrophizing thoughts, and encouraging graded exposure to movement, physiotherapists can help patients re-engage with life despite chronic pain.

Tailored Rehabilitation: Patient-centered care in physiotherapy involves developing individualized treatment plans that are shaped by the patient's specific needs, preferences, and goals[39]. This personalized approach ensures that patients feel heard and involved in their own care. It also acknowledges the variability in how pain is experienced across different individuals, further aligning with the neuromatrix's understanding of the pain experience as highly individualistic and dynamic. Physiotherapists also work with patients to address the social factors contributing to chronic pain. This includes considering workplace environments, family dynamics, and community support, which can all impact a patient's recovery. By incorporating these elements into treatment plans, physiotherapy can help mitigate external stressors that may worsen pain perception.

CHALLENGES AND FUTURE DIRECTIONS

Lack of Standardized Protocols: While the neuromatrix theory provides a broad conceptual framework for understanding chronic pain, there are no universally accepted, standardized protocols for its application in physiotherapy. The field lacks clear guidelines on how to systematically incorporate neuromatrix principles into treatment plans. For instance, while neuroplasticity techniques such as graded motor imagery are effective for certain conditions, their use is not widespread across physiotherapy settings due to a lack of consensus on how best to implement them[40].

Limited Training for Clinicians: Many physiotherapists are not fully trained in the application of the neuromatrix model in clinical practice. This limits their ability to address the cognitive, emotional, and sensory components of pain in an integrated manner[41]. While cognitive-behavioral techniques, manual therapy, and movement interventions are common, the holistic approach of addressing the brain's pain networks may not be emphasized enough in physiotherapy education and practice.

Patient Adherence to Multidimensional Approaches: A significant challenge is encouraging patient adherence to the multifaceted treatments required in neuromatrix-based physiotherapy. Treatment plans often involve a combination of manual therapy, exercise, education, and cognitive techniques, but patients may struggle to engage consistently in such comprehensive programs. Addressing the emotional and psychological aspects of chronic pain requires patience, motivation, and the active participation of the patient, which can be a barrier in many cases[42].

POTENTIAL INNOVATIONS IN PAIN THERAPY

The future of neuromatrix-based physiotherapy in pain management holds significant promise, particularly with the advent of technological innovations that can enhance treatment delivery:

Artificial Intelligence (AI) in Pain Therapy: AI technologies hold great potential in personalizing pain management[43]. AI algorithms could analyze vast amounts of patient data (e.g., pain history, sensorimotor data, psychological profiles) to tailor treatment plans more precisely to the individual's unique pain experience. Machine learning could help predict how a patient's pain will respond to different interventions, creating highly personalized care plans that adjust dynamically over time. For example, AI could optimize the delivery of graded motor imagery or help identify the most effective combination of manual therapy and exercise programs based on a patient's progress.

Virtual Rehabilitation: Virtual reality (VR) and augmented reality (AR) are emerging tools in the rehabilitation of chronic pain[44]. These technologies can be used to create immersive environments that engage patients in movement exercises, neuroplasticity training, and pain education. VR has been shown to reduce pain perception and improve mobility in patients with conditions such as phantom limb pain and fibromyalgia by providing controlled, safe, and engaging environments for pain management[45]. Virtual rehabilitation could become an essential tool for physiotherapists, allowing them to remotely monitor patients, provide real-time feedback, and adjust interventions to enhance engagement and effectiveness.

Personalized Treatments: Advances in wearable technology, such as smart devices and biofeedback tools, could provide real-time data on a patient's physical activity, movement patterns, and pain responses[46]. Physiotherapists could use this data to adjust treatments in real-time, allowing for a truly personalized approach to pain management. These technologies could also help track and enhance neuroplastic changes in the brain, further improving the application of neuromatrix-based physiotherapy.

DISCUSSION

This scoping review examined how physiotherapy interventions align with the Neuromatrix Theory of Pain in the management of chronic pain. The findings demonstrate a shift from traditional biomedical approaches toward integrative, neuromatrix-informed strategies that address cognitive, emotional, and sensory factors[15, 16]. These approaches reflect the increasing adoption of the biopsychosocial model[11], supporting a more individualized and patient-centered framework for chronic pain rehabilitation.

Physiotherapy interventions such as pain neuroscience education[43], graded motor imagery[31], neuroplasticity-based exercises[30], and biopsychosocial-focused rehabilitation programs[29, 33] have been shown to target central pain mechanisms. These techniques aim to modulate the neuromatrix by addressing maladaptive patterns such as catastrophizing, fear avoidance, and altered sensorimotor processing[24, 35]. For instance, studies on phantom limb pain[23] and fibromyalgia[22] provide evidence of brain-based pain generation and support interventions that retrain cortical representations.

The therapeutic alliance, patient beliefs, and pain literacy are also key components in neuromatrix-aligned physiotherapy. Educating patients about the brain's role in pain and encouraging active participation fosters improved coping and reduced reliance on passive treatments[43]. This aligns with cognitive-behavioral and mindfulness-based approaches increasingly incorporated into physiotherapy practice[37, 38].

However, challenges to implementation remain. There is no standardized protocol for delivering neuromatrix-based interventions[40], and many physiotherapists lack formal training in integrating psychological and neuroeducational components[41]. Patient adherence can also be a barrier, as multimodal care requires sustained engagement and self-management[42]. These gaps highlight the need for expanded clinical education and clearer practice guidelines.

Emerging innovations offer potential to address these limitations. Virtual reality and augmented reality tools have shown early success in pain modulation and functional improvement[44, 45]. Wearable technologies and AI-driven feedback systems may further personalize rehabilitation and support neuroplasticity-driven recovery[43, 46].

In summary, the integration of the Neuromatrix Theory into physiotherapy represents a promising evolution in the management of chronic pain. By targeting the dynamic interactions within the brain's pain matrix and addressing biopsychosocial factors, physiotherapy can deliver more holistic, adaptive, and evidence-based care. Nonetheless, further high-quality research and implementation frameworks are required to validate these approaches and improve accessibility across diverse healthcare contexts.

CONCLUSION

This scoping review emphasizes the importance of integrating the Neuromatrix Theory into physiotherapy for effective chronic pain management. The key takeaways highlight that pain is not just a sensory experience but a complex interaction of sensory, cognitive, and emotional factors processed by the brain. Physiotherapy, through manual therapy, movement-based interventions, and neuroplasticity techniques, aligns well with this model by addressing all these dimensions. Emerging technologies like AI, virtual rehabilitation, and wearable devices offer exciting opportunities for more personalized and adaptive pain management.

The integration of the Neuromatrix Theory into physiotherapy helps shift the focus from simply treating physical symptoms to addressing the multifactorial nature of pain, leading to more holistic, patient-centered care.

From a public health perspective, embracing the neuromatrix-informed physiotherapy paradigm offers a scalable and sustainable strategy to address the chronic pain crisis. It supports health system resilience by promoting preventive care, reducing healthcare costs, and improving quality of life across diverse populations. As such, advancing public awareness, access to skilled physiotherapy services, and interdisciplinary collaboration is imperative in transforming the pain care landscape and mitigating its widespread impact on global health.

Ethical Consideration:
As this study is a scoping review of published literature, it did not involve any direct human or animal participants, and thus did not require formal ethical approval. All data were obtained from peer-reviewed and publicly accessible sources. The review was conducted in accordance with the principles of transparency, integrity, and proper citation of original work

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