RESEARCH PAPER

SENSORIMOTOR AND NEUROPLASTICITY-BASED INTERVENTIONS FOR CHRONIC MUSCULOSKELETAL PAIN: A SYSTEMATIC REVIEW

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ABSTRACT
Background: Chronic musculoskeletal pain is characterized by lasting pain, disability, and impaired sensory-motor processing. Use of physiotherapy modalities that enhance sensory control and neuroplasticity could be beneficial.
Objective: The aim of this study was to assess the impact of physiotherapy treatments aimed at sensory-motor control or neuroplasticity in chronic musculoskeletal pain.
Methods: The methodology used involved systematic review according to PRISMA 2020 guidelines. The following databases were searched: PubMed, Scopus, Web of Science, Embase, Pedro, Cochrane CENTRAL. The studies were eligible if they analyzed physiotherapy treatments based on the mechanisms of sensory-motor control or mechanisms of pain in the brain. Risk of bias was assessed, and results were analyzed and discussed.
Results: After screening 1,526 of 2,210 records left after removal of duplicates and assessing 126 reports, 28 studies were included in the review. The interventions studied were sensorimotor training, motor control training, proprioceptive exercises, and pain neuroscience education combined with exercise as well as graded motor imagery and motor imagery. Different types of interventions improved pain and disability, but their superiority over active controls is not conclusive and has also been limited by methodological diversity. The evidences about rehabilitation-based neuromodulation remained weak.
Conclusion: the interventions focused on sensorimotor rehabilitation and neuroplasticity might have a positive impact on pain and functioning in patients suffering from chronic pain syndrome, however, the evidences are still unclear.
Keywords: Chronic pain; Sensorimotor rehabilitation; Neuroplasticity; Motor training; Pain neuroscience education; Physiotherapy.
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1. INTRODUCTION

Chronic musculoskeletal pain (CMP) has a significant role in disability, restricted physical performance, and lower quality of life. The pathophysiological relationship of CMP with structural pathology or injuries does not explain its sustained occurrence. Nociceptive mechanisms, sensory processes, motor functions, psychological influences, and CNS processes are interconnected in chronic musculoskeletal pain. Sensorimotor processing dysfunctions may comprise those in proprioception, body image, motor images, sensory ability, and motor skills, which may lead to prolonged pain and limitations in functioning.

Neuroplastic changes due to prolonged pain may alter the perception of pain, body image, movement patterns, and performance in general. Hence, increased sensitivity and altered endogenous pain modulation has grown to be critical components in rehabilitation of injuries affecting musculoskeletal system[1,6–9,11–13]. The specific physiotherapy treatment strategies for CMP include motor control and sensorimotor approaches, proprioceptive and neuromuscular exercises, movement training, graded and non-graded imagery, and rehabilitation methods combining pain education and physical therapy. Techniques such as transcranial direct current stimulation (tDCS) or repetitive transcranial magnetic stimulation (rTMS) [26,27]may also be included in conjunction with non-invasive neurological methods. Previous systematic analyses have explored one type of intervention or one type of pain, leading to diverse information for the population of musculoskeletal disorders or pain checking. Muscular disorders and pain-related conditions can be analyzed more as a whole, and this shows the reason for the present study that would evaluate the influence of physiotherapy based on sensorimotor and neuroplasticity approaches on pain and functional outcomes for the population of chronic musculoskeletal pain. The outcomes of the study will indicate its effect on several factors including quality of life, sensorimotor functioning, psychological and physical outcomes, and pain central processing.

2. MATERIALS AND METHODS

2.1 Search Strategy and Eligibility Criteria

The systematic review adhered to PRISMA 2020 and utilized the PICO framework for the purpose of this study. Adults of 18 years and older (≥18 years old) suffering from chronic musculoskeletal pain (≥3 months) were eligible to take part in the research. Eligible conditions include chronic lower back pain, chronic neck pain, chronic shoulder pain, osteoarthritis of the knee, and others [1–28]. The revisions reviewed interventions targeting sensorimotor integration, motor controls, processing of sensory system information, and neuroplasticity, which included sensorimotor training, proprioceptive/neuromuscular exercises, motor or graded motor imagery, cognitive-motor rehabilitation, and pain neuroscience education (PNE) coupled with rehabilitation practices. Evidence involving transcranial direct current stimulation (tDCS) or repetitive transcranial magnetic stimulation (rTMS) is included in the review only when combined with rehabilitation [26,27].

2.2 Information Sources and Study Selection

Since January of 2010 until August of 2026, searches were conducted in multiple databases including PubMed/MEDLINE, Scopus, Web of Science, Embase, PEDro and Cochrane CENTRAL [1–28]using different terminology to search for chronic musculoskeletal pain, sensorimotor/neuroplastic based strategies and rehabilitation. In addition, the reference lists and citations were also checked. After removing any duplicate content, the eligibility of titles or abstracts was checked and reasons for exclusion were noted. The selection was carried out as per the PRISMA 2020 guidelines.

2.3 Data Extraction and Risk of Bias

The information obtained included details about the participants, the types of intervention used, the types of comparison group, the duration of the treatment, the results observed, following events, adverse side effects, funding and conflicts of interest. The RoB 2 tool was employed to assess the risk of bias whereas the ROBINS-I tool was used wherever appropriate. Any dissenting opinions were resolved either through discussions or through the involvement of a third party reviewer.

2.4 Data Synthesis and Certainty of Evidence

Since there was variation in clinical and methodological aspects, findings were compiled in a narrative way based on condition, intervention, control, outcome, and follow-up. Meta-analysis was conducted only if the studies were comparably adequate. Publication bias and strength of evidence were assessed by proper techniques including GRADE. There was no requirement for ethical approval since only published data had been used.

3. Results

3.1 Study Selection and Characteristics

The database search yielded 2,210 records. After eliminating 684 duplicates, 1,526 records were screened by title and abstract. Out of these, 134 records were deemed potentially eligible, and 126 full-text articles were evaluated after excluding any inaccessible or duplicate records. During the process of full-text evaluation, 98 articles were excluded due to a variety of factors including wrong study population, intervention, control group, outcome, study design, or inadequate relevance to sensorimotor or neuroplastic rehabilitation. Ultimately, 28 randomized controlled trials fulfilled the eligibility requirements for inclusion in this systematic review. The study-selection process is presented in the PRISMA flow diagram (Figure 1).

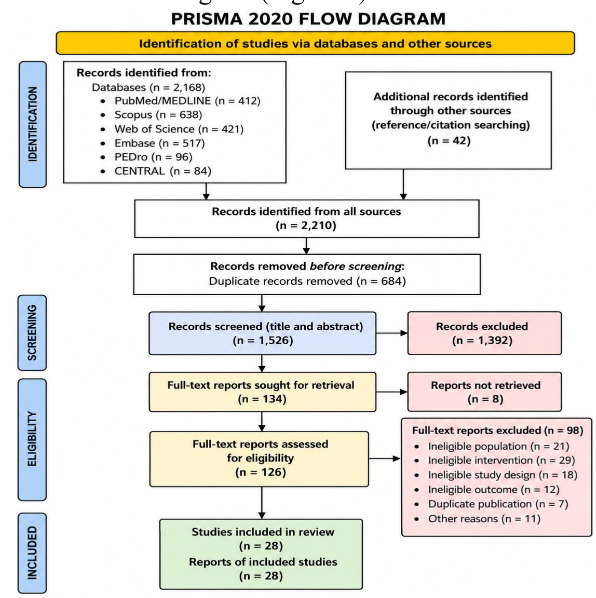

Figure 1. PRISMA 2020 flow diagram of the study selection process.

The included studies evaluated adults with chronic musculoskeletal pain, including chronic low-back and neck pain, knee osteoarthritis, shoulder pain, fibromyalgia, and other persistent musculoskeletal pain conditions. Interventions included motor-control and sensorimotor training, proprioceptive and neuromuscular exercise, pain neuroscience education combined with exercise, graded motor imagery or motor imagery, and rehabilitation-integrated neuromodulation. Intervention duration and outcome measures varied substantially across studies.

Table 1. Characteristics of Studies Relevant to Sensorimotor and Neuroplasticity-Based Physiotherapy Interventions for Chronic Musculoskeletal Pain.

No.	Study	Condition/sample (n)	Intervention vs comparator	Intervention duration	Key outcomes

				on/follow-up	
1	McCaskey et al., 2018	Chronic nonspecific LBP (22)	Sensorimotor training + physiotherapy vs sub-effective exercise + physiotherapy	3 week + follow-up	Functional/postural outcomes improved; pain effects less consistent.
2	Walti et al., 2015	Chronic/recurrent LBP (28)	Neurophysiological education + sensorimotor retraining vs usual physiotherapy	Short-term + follow-up	Feasibility and preliminary clinical benefits reported.
3	Bodes Pardo et al., 2018	Chronic LBP (56)	PNE + therapeutic exercise vs therapeutic exercise	Intervention + follow-up	Additional benefits in pain-related outcomes.
4	Malfliet et al., 2018	Chronic spinal pain (120)	PNE + cognition-targeted motor control vs best-evidence physiotherapy	3, 6, 12 months	Improvements in disability, pain cognitions, and sensitization-related outcomes.
5	Aasa et al., 2015	Mechanical LBP (70)	Low-load motor-control exercise +	8 week + follow-up	Both improved clinical outco

			education vs high-load lifting + education		mes; no clear superiority.
6	Saadat et al., 2019	Chronic nonspecific neck pain (53)	Sensorimotor training + physiotherapy vs traditional physiotherapy	4 week	Greater improvements in sensorimotor and balance outcomes.
7	Rudolfsson et al., 2014	Chronic nonspecific neck pain (108)	Neck coordination/sensorimotor exercise vs resistance exercise/ control	11 week+ follow-up	Sensorimotor function improved; clinical effects mixed.
8	Nusser et al., 2021	Chronic neck pain (51)	VR-based neck-specific sensorimotor training vs standard rehabilitation	3 week	Headache and cervical ROM improved.
9	Khosrokiani et al., 2022	Chronic neck pain (113)	Motor-control exercise vs alternative motor-control/control	8 week	Several clinical and functional outcomes improved.
10	Sremakaew et al., 2023	Neck pain with sensorimotor	Cervical sensorimotor training + local	6 week	Selected sensorimotor outco

		deficits (152)	treatment vs alternative treatment		mes improved; effects varied by combination.
11	Cho et al., 2015	Knee osteoarthritis (37)	Proprioceptive training vs quadriceps strengthening/control	12 week	Selected biomechanical and functional outcomes improved.
12	Ojoawo et al., 2016	Knee osteoarthritis (45)	Proprioceptive exercise vs isometric quadriceps exercise	6 week	Greater improvements in pain and physical
					difficulty.
13	Gomiero et al., 2018	Knee osteoarthritis (64)	Sensorimotor training vs resistance training	16 week	Both groups improved; sensorimotor training showed functional benefits.
14	Gul et al., 2021	Chronic LBP (31)	Physiotherapy + neuroscience education vs physiotherapy	3 week	Selected clinical and psychological outcomes improved.

15	Rabiei et al., 2021	Chronic LBP (73)	PNE + motor-control exercise vs group exercise	8 week	Favorable changes in pain-related outcomes.
16	Javdaneh et al., 2021	Chronic neck pain (72)	PNE + therapeutic exercise vs therapeutic exercise/control	6 week	Pain-related disability and psychological outcomes improved.
17	Saracoglu et al., 2022	Chronic LBP (69)	PNE + manual therapy + home exercise vs comparator rehabilitation	Treatment + follow-up	Additional effects in selected short- and long-term outcomes.
18	Bagg et al., 2022	Chronic nonspecific LBP (276)	Graded sensorimotor retraining vs sham/attention control	12 week + follow-up	Modest pain improvements persisted at later follow-ups.
19	Gorji et al., 2022	Chronic LBP (37)	PNE + motor-control exercise vs core-stability exercise	8 week	Greater pain reduction; other effects mixed.
20	de Sousa et al., 2024	Fibromyalgia (75)	Aquatic exercise + PNE vs aquatic exercise	12 week + follow-up	Limited additional pain benefit; some

					secondary benefits.
21	Kircali et al., 2024	Fibromyalgia with chronic back pain (50)	Motor-imagery exercise ± PNE vs control	Intervention period	Active interventions reduced pain; PNE improved selected pain-related beliefs.
22	Araya-Quintanilla et al., 2024	Fibromyalgia (65)	GMI + neuroscience education + multicomponent treatment vs standard treatment	12 week	Improvements in pain, functional impact, and psychological outcomes.
23	Farragher et al., 2024	Chronic nonspecific LBP (69)	Neuromuscular-control retraining + resistance exercise vs resistance exercise	12 week	No clinically meaningful additional disability benefit.
24	Fanuscu et al., 2024	Chronic LBP (42)	Motor-control exercise via clinic/telerehabilitation vs alternative delivery	8 week	Both approaches improved clinical outcomes; telerehabilitation

					feasible.
25	Buccioli et al., 2025	Chronic rotator-cuff-related shoulder pain (70)	Proprioceptive + strengthening exercise vs strengthening	2 months	Both improved; proprioceptive addition not superior.
26	Alcon et al., 2025	Chronic LBP with high catastrophizing (20)	tDCS + PNE vs sham tDCS + PNE	2 week	Active neuromodulation improved selected pain-related outcomes.
27	ExTraStim Trial, 2026	Chronic nonspecific LBP (140)	rTMS + motor-control exercise vs active/sham rTMS + exercise	8 week	Pain improved over time; no clear superiority of combined treatment.
28	Rodriguez-Dominguez et al., 2026	Fibromyalgia (60)	PNE + resistance training vs aerobic + flexibility exercise	Intervention period	Improvements in pain and disability; selected secondary benefits.

Abbreviations: LBP, low-back pain; PNE, pain neuroscience education; GMI, graded motor imagery; ROM, range of motion; tDCS, transcranial direct current stimulation; rTMS, repetitive transcranial magnetic stimulation; VR, virtual reality.

3.2 Risk of Bias of Included Studies

The Cochrane's Risk of Bias 2 or RoB 2 tool was used to assess the risk of bias. Each judgment on risk of bias took account of five aspects: process of randomization, deviations from the intended intervention, missing data about the outcome, outcome measurement, and reporting outcomes. The majority of concerns present in these studies relate to deviations from the intended intervention. Some studies dealt with outcome measurement and selective reporting. The findings reveal that mostly, the risk of bias in the studies is judged as having some concerns, with a smaller number of studies showing low overall risk of bias. Detailed assessment of each aspect is given in table 2.

Table 2. Risk of Bias Assessment of the Included Randomized Controlled Trials

Study	**R**	**D**	**M**	**O**	**S**	**Overall**
McCaskey et al., 2018	L	SC	L	L	L	SC
Wälti et al., 2015	SC	SC	L	L	L	SC
Bodes Pardo et al., 2018	SC	SC	L	L	L	SC
Malfliet et al., 2018	L	SC	L	L	L	SC
Aasa et al., 2015	L	SC	L	L	L	SC
Saadat et al., 2019	L	SC	L	SC	SC	SC
Rudolfsson et al., 2014	L	SC	L	L	L	SC
Nusser et al., 2021	L	SC	L	SC	SC	SC
Khosrokiani et al., 2022	L	SC	L	SC	L	SC
Sremakaew et al., 2023	L	SC	L	SC	L	SC
Cho et al., 2015	L	SC	L	SC	SC	SC
Ojoawo et al., 2016	SC	SC	SC	SC	SC	SC
Gomiero et al., 2018	L	SC	L	L	SC	SC
Gül et al., 2021	L	SC	L	SC	SC	SC
Rabiei et al., 2021	SC	SC	SC	SC	SC	SC
Javdaneh et al., 2021	L	SC	L	SC	SC	SC
Saracoglu et al., 2022	SC	SC	L	SC	SC	SC
Bagg et al., 2022	L	SC	SC	L	SC	SC
Gorji et al., 2022	L	SC	L	SC	SC	SC
de Sousa et al., 2024	L	SC	SC	SC	SC	SC
Kircali et al., 2024	L	SC	L	SC	SC	SC
Araya-Quintanilla et al., 2024	L	SC	L	SC	SC	SC
Farragher et al., 2024	L	L	L	L	L	L

Fanuscu et al., 2024	L	SC	L	SC	SC	SC
Buccioli et al., 2025	L	SC	L	SC	SC	SC
Alcon et al., 2025	L	SC	SC	SC	SC	SC
ExTraStim Trial, 2026	L	L	L	L	L	L
Rodríguez-Domínguez et al., 2026	L	L	L	L	L	L

Abbreviations: R, randomization process; D, deviations from intended interventions; M, missing outcome data; O, outcome measurement; S, selection of reported result; L, low risk; SC, some concerns.

3.3 Overall Synthesis of Findings

Sensorimotor and motor-control treatments generally led to improvements in pain, disability, function, and sensorimotor function among chronic musculoskeletal pain cases. Proprioceptive and neuromuscular motor training proved efficient, especially in neck pain and knee osteoarthritis pain. Pain neuroscience education combined with exercise resulted in improvement in disability and psychological outcomes, although changes beyond exercise alone were not consistently evident. Graded motor imagery seemed to offer promising prospects for pain management and movement outcomes. Rehabilitation-integrated neuromodulation (tDCS, rTMS) appeared to show good, albeit limited evidence without constant effectiveness.

4. DISCUSSION

This systematic review indicates that physiotherapy interventions based on sensorimotor approaches and neuroplasticity may lead to improvements in the areas of pain, disability, physical functioning and some sensorimotor and psychological results in people suffering from chronic pain conditions. The used interventions harnessing sensorimotor and motor control exhibited good overall results, especially among patients suffering from chronic low-back pain and neck pain[1–10,14–19,23,24], while some functional goals were achieved with the application of proprioception and neuromuscular methods. Pain neuroscience education combined with exercise produced a positive effect on pain disability and psychological parameters, while additional advantages in comparison to exercise alone were unclear. Graded motor imagery and motor imagery may be promising methods to be adopted in chronic pain conditions. However, the variety of used treatments and patient population challenges making strong conclusions[11–13,25]. There is little evidence in favor of tDCS and rTMS integrated into rehabilitation which does not prove their advantage over comparing methods. The main limitation was substantial heterogeneity in populations, interventions, treatment duration, comparators, and outcome measures, together with some concerns regarding risk of bias. Furthermore, most studies did not include objective neurophysiological measures; therefore, clinical improvements cannot be directly attributed to neuroplastic changes[21,22]. Future trials should use standardized interventions, adequate sample sizes, clinically meaningful outcomes, longer follow-up, and objective measures of sensorimotor or neuroplastic change.

5. CONCLUSION

Physiotherapy interventions based on sensory-motor and neuroplasticity techniques can help to reduce pain, disability, improve mobility, and improve selected sensory-motor outcomes [1–28] in individuals that suffer from chronic musculoskeletal pain. Nonetheless, its advantage over active rehabilitation is uncertain, and heterogeneity as well as the risk of bias diminishes the confidence in the findings. For now, neuromodulation therapies integrated with rehabilitation are still being studied[26,27]. The use of individualized multimodal rehabilitation that involves sensory, motor, and cognitive techniques exhibits promise in the treatment of chronic musculoskeletal pain.

Declarations

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Conflict of Interest: The author confirms that there are no conflicts of interest, whether financial, personal, or professional, that could have influenced the content or outcome of this review.

Ethical Approval: As this is a systematic review based solely on previously published literature, no ethical approval was required. The study did not involve any direct research with human or animal subjects.

Publication Statement: The author confirms that this manuscript has not been published previously and is not under consideration by any other journal.

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