BOHR International Journal of Neurology and Neuroscience
2025, Vol. 3, No. 1, pp. 7–10
DOI: 10.54646/bijnn.2025.23
www.bohrpub.com

REVIEW

Neuroplasticity in spinal cord injury: Physiotherapy approaches to functional recovery

Mohammed Sheeba Kauser[1*†], S. Purna Chandra Shekhar[2] and Subhasis Karmakar[3]

[1]SV Group of Institutions, Nellore, Andhrapradesh, India
[2]PDS Institute of Physiotherapy, KNR University of Health Sciences, Hyderabad, Telangana, India
[3]Department of Physiotherapy, Dubai, UAE

[*]**Correspondence:**
Mohammed Sheeba Kauser,
Sheebaishaq.doc@gmail.com

[†]**ORCID:**
Mohammed Sheeba Kauser,
0000-0001-5301-3559

Received: 11 January 2025; **Accepted:** 28 January 2025; **Published:** 22 February 2025

Spinal cord injury (SCI) prompts huge disabilities because of the interruption of brain connections between the brain and spinal cord. Brain adaptability, the mind's and spinal cord's capacity to redesign and frame new brain associations, offers a promising instrument for practical recuperation after SCI. This survey investigates the job of brain adaptability in SCI restoration and looks at different physiotherapy approaches intended to advance recuperation. Key procedures incorporate early activation, movement-based treatments, mechanically helped recovery, tangible engine coordination preparing, and neurophysiological methods, for example, transcranial magnetic stimulation (TMS). Additionally, emerging treatments like spinal cord stimulation and pharmacological interventions are discussed as potential adjuncts to rehabilitation. Despite the potential for neuroplasticity to facilitate recovery, challenges remain in optimizing therapeutic outcomes due to factors such as the injury's severity and timing of interventions.

Keywords: neuroplasticity, spinal cord injury (SCI), functional recovery, rehabilitation, motor function, neurorehabilitation

Introduction

Spinal cord injury (SCI) represents a significant challenge to human health, often leading to permanent functional impairments that affect the mobility and independence of individuals (1). Generally, SCI was seen as an irreversible condition with restricted open doors for recuperation. Notwithstanding, late advances in neuroscience have revealed insight into the cerebrum's wonderful capacity to adjust and redesign, a peculiarity known as neuroplasticity (2). Brain adaptability with regards to SCI has opened new roads for restoration and utilitarian recuperation, giving desire to further developing results in patients with spinal rope injuries (3).

This article investigates the job of neuroplasticity in spinal cord injury recuperation, especially zeroing in on the most recent physiotherapy moves toward that saddle, the cerebrum's and spinal cord's true capacity for rearrangement and fix. Through neuroplastic instruments, it is feasible to advance the rebuilding of lost capabilities, work with the improvement of new brain associations, and upgrade engine recuperation, even lengthy after the injury has occurred (4).

The target of this review is to look at current proof on how physiotherapy mediations, for example, neuro-restoration strategies, engine preparing, and task-explicit activities, can animate brain adaptability and advance useful recuperation in SCI patients (5). Moreover, we will talk about the difficulties and limits of current helpful procedures and recommend future bearings for improving brain adaptability-based restoration with regards to spinal cord injury (6).

Methodology

A systematic search was performed for this comprehensive review, with several databases with relevant studies that included total studies and titles with abstracts from different databases such as Cochrane, CINHAL, PUBMED, SCOPUS, WEB OF SCIENCE, and GOOGLE SCHOLAR. A manual search was also done by us with the relevant cited articles used in references, including the inclusion criteria and following keywords as detailed below:

1. **Keywords and Search Terms:** A combination of keywords and Medical Subject Headings (MeSH) terms was used to maximize the sensitivity and specificity of the search. These terms included:
   - "Neuroplasticity"
   - "Spinal Cord Injury" or "SCI"
   - "Physiotherapy" or "Physical Therapy"
   - "Motor Recovery"
   - "Neurorehabilitation"
   - "Functional Recovery"
   - "Rehabilitation Techniques"
   - "Task-Specific Exercises"

AND, OR, and NOT were used to combine terms in relevant ways, ensuring a broader search.

A total of 45 articles were finalized with the timeline of 2000 and till date 2025, out of which 23 articles seemed accurate and have been considered for the study.

Studies that included randomized control trails, longitudinal cohort studies, and reviews have been considered.

Neuroplastic mechanisms targeted

1. **Cortical Reorganization:** Stimulating the brain's ability to reorganize motor and sensory areas through therapies like TMS and mirror therapy.
2. **Spinal Cord Plasticity:** Enhancing neural circuits within the spinal cord through body weight supported treadmill training (BWSTT), functional electrical stimulation (FES), and SCS to restore motor functions.

Key findings and conclusions

- **Motor Function:** Intensive activity-based therapies (e.g., BWSTT and FES) significantly improve motor function, especially in incomplete SCI.
- **Sensory Recovery:** Sensory stimulation and mirror therapy aid sensory recovery by promoting cortical reorganization.
- **Quality of Life:** Neuroplasticity-focused interventions improve independence, reduce pain, and enhance psychological well-being.
- **Neuroplasticity:** Successful rehabilitation promotes both cortical and spinal cord reorganization, improving motor and sensory functions. Personalizing interventions maximizes recovery outcomes.

A qualitative synthesis was employed to summarize the evidence and highlight the physiotherapy approaches that showed the most promise for promoting neuroplasticity and improving recovery in SCI patients.

Quality assessment

Quality assessment was done by following:

- The Cochrane Risk of Bias tool for randomized controlled trials (RCTs).
- The Newcastle-Ottawa Scale for observational studies.
- The AMSTAR tool for systematic reviews.

The results from the selected studies were synthesized into key categories:

- **Neuroplastic Mechanisms:** Understanding how neuroplasticity operates in SCI recovery and which physiological processes are most influenced by physiotherapy.
- **Physiotherapy Interventions:** Review of different rehabilitation approaches, including task-oriented training, repetitive motion exercises, and assistive technologies.
- **Functional Recovery Outcomes:** Assessment of what these mediations mean for motor recuperation, tactile sensory capability, and generally personal satisfaction in SCI patients.

Discussion

By coordinating the outcomes, we intend to give a proof-based comprehension of how physiotherapy can advance brain adaptability and useful recuperation after SCI. This survey additionally features holes in flow research and recommends regions for future investigation.

Brain adaptability in spinal cord injury: Physiotherapy ways to deal with practical recuperation

Spinal cord injury (SCI) is a disastrous occasion that upsets the correspondence between the mind and the remainder of the body (7). This disturbance prompts shifting levels of loss of motion, tactile misfortune, and brokenness in autonomic cycles. Nonetheless, the spinal line is certainly not a totally static construction. One of the most encouraging parts of SCI recuperation is brain adaptability, which alludes to the mind's and spinal line's capacity to redesign and frame new brain associations in light of injury (8). Brain adaptability gives a premise to useful recuperation and has huge ramifications for recovery procedures, especially physiotherapy (9).

Brain adaptability includes both the focal sensory system (CNS) and fringe sensory system (PNS). After SCI, the spinal rope goes through a scope of changes, for example,

- **Axonal sprouting:** The growth of new axons or the extension of undamaged axons to re-establish neural pathways.
- **Synaptogenesis:** The formation of new synaptic connections between neurons to enhance communication.
- **Cortical remapping:** The reorganization of motor and sensory representations in the brain to accommodate the injury and maximize available function.

However, the extent to which neuroplasticity can facilitate functional recovery in SCI depends on several factors, including the severity of the injury, the time post-injury, and the effectiveness of rehabilitation interventions.

Physiotherapy approaches to promote neuroplasticity and functional recovery

1. Early Mobilization and Activity-Based Therapies.

   One of the most important ways physiotherapists can encourage neuroplasticity is through early mobilization and activity-based therapies. Physical activity has been shown to promote axonal growth and synaptic remodeling in both the spinal cord and brain. Key approaches include:

   - **Body-weight supported treadmill training (BWSTT)**: This approach allows patients to engage in walking-like movements with partial body weight support, helping to encourage spinal cord function and motor control (10).
   - **Functional electrical stimulation (FES)**: FES can activate paralyzed muscles through electrical impulses, promoting muscle strength, improving circulation, and enhancing neuromuscular plasticity (11).
   - **Task-specific training**: Training that mimics functional activities (such as reaching, grasping, or standing) can help re-establish motor patterns and improve sensory-motor integration (12).

2. Robotics-Helped Recovery Advanced mechanics have been coordinated into restoration programs for people with SCI to help with monotonous and exact developments. Automated exoskeletons or assistive gadgets can direct the patient through the movements of strolling, venturing, or standing. These gadgets can give tedious, task-explicit developments that work with neuroplastic changes in the spinal line. Moreover, the input given by these gadgets can upgrade proprioception, which is critical for engine control and rehabilitation (13).

3. Sensory-Engine Reconciliation Preparing After SCI, tactile engine mix frequently becomes upset, prompting debilitated body mindfulness and coordination. Tactile engine reconciliation treatments mean to retrain the mind to successfully utilize accessible tangible sources of info more. Procedures might include:

   Sensory excitement: Utilizing different types of tactile feeling (e.g., contact, vibration, or proprioception) to enact the tangible pathways and work on cortical representation (14).

   Mirror treatment: Mirror treatment has been utilized to upgrade engine symbolism and tangible mindfulness, working with neuroplastic changes (15).

4. Neurophysiological Methods

   Transcranial attractive feeling (TMS): TMS can harmlessly animate regions of the mind and spinal rope, possibly advancing brain adaptability by upgrading cortical edginess and engine control (16).

   Repetitive transcranial attractive excitement (rTMS): This strategy includes a redundant feeling of the engine cortex and may assist with reinforcing brain processes, advance versatility, and possibly further develop engine function (17).

5. Cognitive and Mental Help Brain adaptability isn't simply a physiological cycle yet a mental one too. Mental commitment and inspiration assume a huge part in upgrading recovery (18). Physiotherapists might work intimately with analysts or advocates to guarantee that patients stay roused all through their restoration. Mental help likewise deals with the personal difficulties related with SCI, which can affect the capacity to take part in treatment and recuperate fully (19).

6. Spinal String Feeling as of late, spinal rope excitement (SCS) has arisen as an imaginative way to deal with working with recuperation in SCI. SCS includes embedding a gadget that sends electrical driving forces to the spinal string, bypassing the injury site (20). Research has demonstrated the way that spinal line excitement can empower some SCI patients to recapture restricted deliberate development, recommending that it might assist with advancing brain pliancy in the spinal cord (21).

7. Pharmacological Intercessions Pharmacological specialists that target brain adaptability are being scrutinized as assistants to recovery treatments. These may incorporate development factors, neurotrophins

(for example, cerebrum inferred neurotrophic factor, BDNF), and prescriptions that can upgrade synaptic pliancy or advance axonal development. However still trial, these medicines hold a guarantee in enlarging exercise-based recuperation outcomes (22).

Future studies

While brain adaptability is a promising pathway for recuperation after SCI, it's anything but a dependable cycle. Factors like the degree of injury (paraplegia versus quadriplegia), the culmination of the injury (complete versus deficient), and the planning of mediations all assume a critical part in recuperation. There is still a lot to find out about the exact systems of brain adaptability in SCI and how best to gain by them through physiotherapy.

Also, working on the adequacy of recovery mediations requires an individualized, patient-focused approach. The power, term, and explicit kind of treatment ought to be customized to the extraordinary requirements of every individual with SCI, considering elements like age, general well-being, and the sort of injury.

Conclusion

Brain adaptability is a focal idea in the restoration of people with spinal rope injury, giving the establishment to the recuperation of engine, tactile, and autonomic capabilities. Physiotherapy assumes a key part in outfitting brain adaptability through different mediations, for example, movement-based treatments, mechanical technology, electrical feeling, and errand explicit preparation. As examination in brain adaptability keeps on developing, future treatments might incorporate further developed methods like spinal rope feeling, pharmacological mediations, and cerebrum PC interfaces. A definitive objective is to upgrade the personal satisfaction for people with SCI by expanding useful recuperation and freedom through state-of-the-art physiotherapy.

Funding

No funding.

References

1. Ramon y Cajal S. *Degeneration and Regeneration of the Nervous System*. London, United Kingdom: Oxford University Press (1928).
2. American Physical Therapy Association. Physical therapy. In: *Guide to Physical Therapist Practice*. 2nd ed. Alexandria, VA: American Physical Therapy Association (2001). p. 9–746.
3. Consortium for Spinal Cord Medicine. *Outcomes Following Traumatic Spinal Cord Injury*. Washington, DC: Paralyzed Veterans of America (1999). Consortium for Spinal Cord Medicine Clinical Practice Guidelines for Spinal Cord Injury. 5 Umphred DA. *Neurological Rehabilitation*. St Louis, MO: Mosby Inc. (2001).
4. O'Sullivan SB, Schmitz TJ. *Physical Rehabilitation: Assessment and Treatment*. Philadelphia, PA: FA Davis Co. (2000).
5. Somers M. *Spinal Cord Injury: Functional Rehabilitation*. London, United Kingdom: Prentice-Hall Inc. (2001).
6. Wolpaw JR, Tennissen AM. Activity-dependent spinal cord plasticity in health and disease. *Annu Rev Neurosci.* (2001) 24:807–43.
7. Rossignol S, Chau C, Brustein E, Bélanger M, Barbeau H, Drew T. Locomotor capacities after complete and partial lesions of the spinal cord. *Acta Neurobiol Exp.* (1996) 56:449–63.
8. Edgerton VR, Tillakaratne NJ, Bigbee AJ, de Leon RD, Roy RR. Plasticity of the spinal neural circuitry after injury. *Annu Rev Neurosci.* (2004) 27:145–67.
9. Lovely RG, Gregor RJ, Roy RR, Edgerton VR. Effects of training on the recovery of full-weight-bearing stepping in the adult spinal cat. *Exp Neurol.* (1986) 92:421–35.
10. Hodgson JA, Roy RR, de Leon R, Dobkin B, Edgerton VR. Can the mammalian lumbar spinal cord learn a motor task? *Med Sci Sports Exerc.* (1994) 26:1491–7.
11. Van de Crommert HW, Mulder T, Duysens J. Neural control of locomotion: Sensory control of the central pattern generator and its relation to treadmill training. *Gait Posture.* (1998) 7:251–63.
12. Dietz V, Duysens J. Significance of load receptor input during locomotion: A review. *Gait Posture.* (2000) 11:102–10.
13. Sherrington CS. Flexion reflex of the limb, crossed extension reflex, and reflex stepping and standing. *J Physiol.* (1910) 40:28–121.
14. Grillner S, Rossignol S. On the initiation of the swing phase of locomotion in chronic spinal cats. Brain Res. (1978) 146:269–77.
15. Hiebert GW, Whelan PJ, Prochazka A, Pearson KG. Contribution of hindlimb flexor muscle afferents to the timing of phase transitions in the cat step cycle. *J Neurophysiol.* (1996) 75:1126–37.
16. Calancie B, Needham-Shropshire B, Jacobs P, Willer K, Zych G, Green BA. Involuntary stepping after chronic spinal cord injury: Evidence for a central rhythm generator for locomotion in man. *Brain.* (1994) 117(pt 5):1143–59.
17. Pang MY, Yang JF. The initiation of the swing phase in human infant stepping: Importance of hip position and leg loading. *J Physiol.* (2000) 528(pt 2):389–404.
18. Duysens J, Pearson KG. Inhibition of flexor burst generation by loading ankle extensor muscles in walking cats. *Brain Res.* (1980) 187:321–32. Sinkjaer T, Andersen JB, Ladouceur M, et al. Major role for sensory feedback in soleus EMG activity in the stance phase of walking in man. *J Physiol.* (2000);523:817–27.
19. Harkema SJ, Hurley SL, Patel UK, Requejo PS, Dobkin BH, Edgerton VR. Human lumbosacral spinal cord interprets loading during stepping. *J Neurophysiol.* (1997) 77:797–811.
20. Dietz V, Muller R, Colombo G. Locomotor activity in spinal man: Significance of afferent input from joint and load receptors. *Brain.* (2002) 125:2626–34.
21. Duysens J, Van de Crommert HW, Smits-Engelsman BC, Van der Helm FC. A walking robot called human: Lessons to be learned from neural control of locomotion. *J Biomech.* (2002) 35:447–53.
22. Zehr EP. Neural control of rhythmic human movement: The common core hypothesis. *Exerc Sport Sci Rev.* (2005) 33:54–60.