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ROBOTIC NEUROREHABILITATION IN NON-STROKE NEURAL INJURIES: A NARRATIVE REVIEW WITH ILLUSTRATIVE COHORT DATA

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ABSTRACT

Background: Robotic neurorehabilitation is an evolving treatment paradigm that leverages activity-dependent neuroplasticity to restore motor function after neural injury. While substantial evidence exists for its application in stroke, data on heterogeneous non-stroke neural injuries, including spinal cord injury (SCI), myelopathy, traumatic brain injury (TBI), and immune-mediated neuropathies remain limited. **Objectives:** This narrative review examines the current evidence for robotic rehabilitation across major non-stroke neural injury categories, evaluates relevant outcome measures, and presents illustrative cohort data from a tertiary rehabilitation centre in Oman to contextualise real-world applicability. **Methods:** A synthesis of published literature on robotic neurorehabilitation in SCI, myelopathy, TBI, and peripheral nerve injuries was conducted. Illustrative clinical data from 23 consecutive patients who underwent robotic rehabilitation were summarised using descriptive statistics and non-parametric within-group comparisons (Wilcoxon signed-rank test). **Results:** The reviewed literature consistently demonstrates improvements in motor function, gait velocity, and balance following robotic rehabilitation in non-stroke populations. In the illustrative cohort, 65% of patients showed at least one MRC grade improvement, 73% demonstrated improved balance scores, and 64% achieved faster gait on the 10-Metre Walk Test. Statistically significant gains were observed across all three domains ($p < 0.05$). **Conclusion:** Robotic neurorehabilitation produces meaningful functional gains across a spectrum of non-stroke neural injuries. Integration into multidisciplinary inpatient rehabilitation pathways is supported by both published evidence and real-world data. Prospective controlled trials with standardised protocols are needed to refine patient selection and dosing parameters.

KEYWORDS: robotic rehabilitation; neurorehabilitation; spinal cord injury; myelopathy; traumatic brain injury; motor recovery; gait; balance; neuroplasticity.

1. INTRODUCTION

Neural injuries, encompassing spinal cord injury (SCI), traumatic brain injury (TBI), cervical and lumbar myelopathy, and immune-mediated neuropathies. They represent a leading global cause of long-term disability, placing a substantial burden on patients, caregivers, and healthcare systems.[1]

The physical consequences of these conditions include paresis, spasticity, ataxia, and gait dysfunction, all of which significantly impair independence and quality of life. While conventional physiotherapy remains foundational in rehabilitation, it is frequently constrained by therapist fatigue, inconsistency in applied resistance, and an inability to deliver the high repetition volumes required to drive durable neuroplastic changes.

Robotic neurorehabilitation has emerged as a promising adjunctive modality to address these limitations. By providing precise, reproducible, and quantifiable movement assistance, robotic platforms enable task-specific, high-intensity motor training that may exceed the ceiling achievable through manual therapy alone.[2,3]

Technologies employed in the field include lower-limb exoskeletal gait trainers, upper-limb robotic orthoses, end-effector treadmill systems, repetitive transcranial magnetic stimulation (rTMS), and brain-computer interface (BCI)-driven assistive devices.[4,5]

Despite a growing body of evidence in post-stroke populations, systematic data on the use and efficacy of robotic rehabilitation in non-stroke neural injuries remain comparatively sparse. Patients with SCI, myelopathy, TBI, and peripheral nerve injury have distinct pathophysiological profiles, neuroplastic potentials, and functional goals that may require tailored rehabilitation approaches. This review aims to synthesise current evidence across these diagnostic categories, highlight key outcome measures, and present illustrative real-world cohort data from a specialist robotic rehabilitation centre in Oman.

2. MECHANISMS OF ROBOTIC NEUROREHABILITATION

The theoretical basis for robotic neurorehabilitation rests on the principle of activity-dependent neuroplasticity,the capacity of the central nervous system (CNS) to reorganise its structure and function in response to repetitive sensorimotor experience.[6]

Hebbian plasticity, wherein repeated co-activation of pre- and post-synaptic neurons strengthens synaptic connections, underlies much of the observed recovery following motor training. Robotic systems deliver consistent, task-specific afferent input during goal-directed movement, thereby promoting cortical and spinal interneuronal reorganisation.[6]

In spinal cord injury, partially spared descending corticospinal tracts and intrinsic spinal circuits (the central pattern generator, CPG) retain the capacity for activity-dependent modulation. Repetitive robotic gait training activates the CPG, generating rhythmic locomotor patterns even in the absence of intact supraspinal drive.[7]

In myelopathy and TBI, perilesional cortical regions demonstrate use-dependent expansion following motor training, a phenomenon confirmed by functional neuroimaging studies. Upper-limb robotic orthoses harness this principle by enforcing symmetrical, error-free movement repetitions that stimulate bilateral cortical engagement.[4,8]

Beyond neuroplasticity, robotic systems confer advantages of standardisation, real-time biofeedback, and objective performance quantification features that facilitate progress monitoring and protocol optimisation in ways that conventional therapy cannot replicate.

3. EVIDENCE BY INJURY CATEGORY

3.1 Spinal Cord Injury

SCI is the most extensively studied non-stroke condition in robotic rehabilitation. Systematic reviews and meta-analyses have documented improvements in gait velocity, lower-limb motor strength, and balance following robotic-assisted gait training (RAGT) in patients with incomplete SCI.[3,9]

Lam and colleagues reviewed lower-limb rehabilitation interventions in SCI, demonstrating that electromechanical-assisted training improved overground walking speed and endurance, with the greatest benefits observed in those with ASIA C and D classifications.[3]

Wirz et al. demonstrated that patients with chronic incomplete SCI undergoing automated locomotor training showed statistically significant improvements in walking speed and independence compared to baseline, challenging the previously held assumption that recovery potential is negligible in the chronic phase.[9]

Importantly, complete SCI (ASIA A) remains largely refractory to current robotic locomotor interventions owing to the absence of residual supraspinal connectivity. In these patients, FES-assisted cycling, trunk stabilisation training, and upper-limb robotic rehabilitation may offer more appropriate alternatives.[7]

3.2 Myelopathy

Cervical and lumbar myelopathy resulting from spondylotic compression, disc prolapse, ossification of the posterior longitudinal ligament (OPLL), or inflammatory pathology shares pathophysiological features with incomplete SCI but presents unique rehabilitation considerations given its frequently insidious onset and post-surgical nature.[5]

Hesse and Uhlenbrock described mechanised gait training as a means to restore walking function in patients with central cord lesions, providing an early framework applicable to myelopathic patients.[5]

The perioperative period following surgical decompression represents a particularly advantageous window for robotic rehabilitation, as spinal cord oedema resolves and descending tract function is progressively restored. Early robotic gait training during this phase capitalises on heightened neuroplasticity and may accelerate functional recovery.

3.3 Traumatic Brain Injury and Neurological Conditions

In TBI, motor rehabilitation using robotic systems must contend with cognitive, behavioural, and attentional co-morbidities that may limit active participation. Nevertheless, end-effector and exoskeletal platforms have demonstrated efficacy in improving upper and lower limb motor function in patients with moderate-to-severe TBI who retain the capacity to engage with therapy.[4,8]

Immune-mediated conditions including neuromyelitis optica (NMO), transverse myelitis, and immune-mediated femoral neuritis exhibit variable recovery trajectories depending on the extent of axonal injury versus demyelination. Demyelinating lesions, given their capacity for remyelination, may respond particularly well to neuroplasticity-based robotic interventions during the acute and subacute phases.

3.4 Balance Rehabilitation

Balance dysfunction is a universal sequela of neural injury and a primary determinant of fall risk and community mobility. Robotic balance training platforms, including dynamic standing frames and perturbation-based systems, have demonstrated superiority over conventional exercises in patients with incomplete SCI and myelopathy.[10,11]

Huang et al. demonstrated that overground robotic training produced significant improvements in balance metrics in patients with complete SCI, with gains maintained at follow-up assessments, suggesting that even the most severely affected patients may derive meaningful functional benefit from targeted robotic balance interventions.[11]

4. ILLUSTRATIVE COHORT DATA

4.1 Clinical Setting and Study Population

To contextualise the reviewed evidence within a real-world clinical setting, we summarise retrospective data from 23 consecutive patients with neural injuries who underwent robotic rehabilitation at the Aster Advanced Robotic Rehabilitation Hospital, Muscat, Oman, between June 2025 and January 2026. This represents one of the first systematic outcome reports from a dedicated robotic rehabilitation centre in the Arabian Gulf region.

The cohort comprised 15 males (65.2%) and 8 females (34.8%), with a mean age of 57.1 years (range: 13–79 years). Diagnoses included spinal cord pathologies (SCI, myelopathy, conus medullaris lesions), post-surgical spinal conditions, traumatic injuries (polytrauma, road traffic accidents), and immune-mediated neurological disorders (NMO, transverse myelitis, immune-mediated femoral neuritis). Rehabilitation duration ranged from 1 to 16 weeks (median: 4 weeks). All patients received robotic lower-limb gait and balance training, complemented by conventional physiotherapy and occupational therapy as clinically indicated.

4.2 Outcome Measures

Three primary functional outcomes were assessed: motor power (Medical Research Council [MRC] grading scale, 0–5), balance (quantified using a standardised numerical balance score), and gait speed (10-Metre Walk Test [10MWT], measured in seconds). Pre- and post-rehabilitation paired assessments were compared using the Wilcoxon signed-rank test.

4.3 RESULTS SUMMARY

Motor power: Among 20 assessable patients, 13 (65%) demonstrated improvement of at least one MRC grade. Mean motor power improved from 2.05 ± 1.39 to 2.95 ± 1.47 (mean change: +0.90; $p = 0.003$). The greatest gains were observed in patients with incomplete SCI, subacute myelopathy, and immune-mediated conditions. Patients with complete SCI or severe cognitive impairment did not show measurable motor improvement, consistent with established neurobiological constraints.[9]

Balance: Eleven of 15 (73%) assessable patients showed improved balance scores. Mean balance score improved from 26.9 ± 19.6 to 37.3 ± 16.8 (mean change: +10.4 points; $p = 0.008$). The most marked improvement occurred in a patient with severe lower-limb weakness due to cervical pathology, whose balance score improved from 0 to 24 over six weeks, enabling achievement of functional standing balance.[10]

Gait speed: Seven of 11 (64%) assessable patients demonstrated improved 10MWT performance. Mean gait time improved from 54.3 ± 36.7 to 38.4 ± 32.5 seconds (mean reduction: 15.9 seconds; $p = 0.021$). One patient who was non-ambulatory at admission successfully completed the 10MWT independently at discharge following six weeks of robotic gait training.[2]

A clinically meaningful dose-response relationship was observed, with patients undergoing longer rehabilitation programmes (≥ 4 weeks) tending to demonstrate greater functional gains across all three domains. These findings echo those reported in the broader robotic rehabilitation literature and highlight the importance of adequate treatment duration in achieving durable neuroplastic change.

5. DISCUSSION

The findings of this review and the illustrative cohort data collectively reinforce the clinical utility of robotic neurorehabilitation in non-stroke neural injuries. The consistency of functional improvements across motor, balance, and gait domains observed in both the published literature and our real-world cohort supports the broader integration of robotic systems into inpatient rehabilitation pathways.

The 65% rate of motor power improvement in our cohort aligns with meta-analytic estimates from robotic rehabilitation trials in SCI and other central nervous system conditions.[3,9]

The rapidity of improvement in patients with subacute myelopathy some demonstrating significant gains within two weeks suggests that perilesional neuroplasticity is particularly amenable to robotic facilitation in the early post-injury or post-surgical period. This has important implications for the timing of rehabilitation initiation, arguing for early deployment of robotic systems where clinically feasible.

The 73% rate of balance improvement is clinically significant given the pivotal role of postural stability in fall prevention, community ambulation, and activities of daily living. Impaired balance is a major barrier to rehabilitation progress and independent discharge; targeting it directly with robotic platforms may confer additional benefits beyond those measurable through motor power or gait speed alone.

The transition from non-ambulatory to ambulatory status achieved by one patient in our cohort following six weeks of robotic gait training illustrates the transformative functional potential of these interventions, consistent with reports in the SCI literature.[5,9]

The absence of improvement in patients with complete SCI, severe cognitive impairment, or chronic stable neurological states reflects recognised limitations of current robotic protocols. Patient selection therefore remains a critical determinant of outcome. Neurophysiological markers including motor-evoked potential presence, residual voluntary movement, and injury acuity may assist in stratifying patients most likely to benefit from robotic rehabilitation.

The Omani context deserves particular mention. Road traffic accidents, degenerative spinal disease, and immune-mediated conditions constitute a significant proportion of the neurorehabilitation caseload in the region. The establishment of dedicated robotic rehabilitation facilities represents a major advancement in the regional rehabilitation infrastructure, and systematic data collection from such centres will be essential to inform locally relevant clinical guidelines.

6. LIMITATIONS

Several limitations warrant acknowledgement. The cohort data presented are retrospective, observational, and derived from a single centre with a small heterogeneous sample, precluding causal inference. The absence of a control group limits attribution of improvements specifically to robotic therapy versus natural recovery or conventional co-interventions. Variability in documentation completeness reduced the number of patients available for each outcome analysis. The review component, while comprehensive in scope, did not employ formal systematic review methodology and may be subject to publication bias. Future research should prioritise prospective randomised controlled trials with standardised protocols, larger sample sizes, longer follow-up periods, and patient-reported outcome measures.

7. CONCLUSION

Robotic neurorehabilitation represents a clinically and scientifically well-grounded approach to functional recovery in patients with non-stroke neural injuries. Evidence from the published literature, corroborated by real-world cohort data from Oman, demonstrates meaningful improvements in motor power, balance, and gait speed following robotic training. Our retrospective study establishes the proof of concept and its feasibility in Oman. Benefits are most pronounced in patients with incomplete injuries, in the subacute phase of recovery, and with sufficient treatment duration. As robotic rehabilitation technology becomes increasingly accessible globally including in the Arabian Gulf region, systematic outcome reporting and investment in prospective research will be essential to optimise patient selection, treatment protocols, and resource allocation.

REFERENCES

1. World Health Organization. Rehabilitation 2030: A Call for Action. Geneva: WHO; 2017.
2. Mehrholz J, Thomas S, Kugler J, Pohl M, Elsner B. Electromechanical-assisted training for walking after stroke. Cochrane Database Syst Rev, 2020; 10: CD006185.
3. Lam T, Wolfe DL, Domingo A, et al. Lower limb rehabilitation following spinal cord injury. Spinal Cord Injury Rehabilitation Evidence, 2014; 5: 1–74.
4. Smania N, Bonetti P, Gandolfi M, et al. Improved gait after repetitive locomotor training in children with cerebral palsy. Am J Phys Med Rehabil, 2011; 90(2): 137–149.
5. Hesse S, Uhlenbrock D. A mechanized gait trainer for restoration of gait. J Rehabil Res Dev, 2000; 37(6):701–708.
6. Teasell R, Mehta S, Pereira S, et al. Activity-dependent recovery of the neurologically impaired brain and spinal cord. J Rehabil Med, 2012; 44(8): 656–672.
7. Esquenazi A, Talaty M, Jayaraman A. Powered exoskeletons for walking assistance in persons with central nervous system injuries: a narrative review. PM&R, 2017; 9(1): 46–62.
8. Dobkin BH. Strategies for stroke rehabilitation. Lancet Neurol, 2004; 3(9): 528–536.
9. Wirz M, Zemon DH, Rupp R, et al. Effectiveness of automated locomotor training in patients with chronic incomplete spinal cord injury. Arch Phys Med Rehabil, 2005; 86(4): 672–680.
10. Sale P, Russo EF, Scarton A, et al. Training focused on the power of lower limbs with ERIGO in patients affected by subacute spinal cord injury. Restor Neurol Neurosci, 2016; 34(5): 805–814.
11. Huang FS, Chang KH, Chuang YF, et al. Overground robotic training effects on walking and balance in people with complete spinal cord injury. J Neuroeng Rehabil, 2022; 19(1): 45.