Ovidius University Annals, Series Physical Education and Sport / SCIENCE, MOVEMENT AND HEALTH
Vol. XXV, ISSUE 2 Supplement, 2025, Romania
The journal is indexed in: ERIH PLUS, Ebsco, SPORTDiscus, INDEX COPERNICUS JOURNAL MASTER LIST, DOAJ DIRECTORY OF OPEN ACCES JOURNALS, Caby, Gale Cengage Learning, Cabell's Directories

Science, Movement and Health, Vol. XXV, ISSUE 2 Supplement, 2025
September 2025, 25 (2): 339-343
Original article

ARM LIGHT EXOSKELETON REHAB STATION (ALEx RS) IN POST-STROKE UPPER LIMB MOBILITY RECOVERY – A CASE STUDY

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Abstract

Aim. The aim of this study is to present the effects of an integrated rehabilitation program using the Arm Light Exoskeleton Rehab Station (ALEx RS) on post-stroke upper limb motor recovery.

Methods. A 71-year-old male patient with left spastic hemiparesis following an ischemic stroke was evaluated and included in a 10-day individualized rehabilitation program at Techirghiol Balneal and Recovery Sanatorium. Clinical evaluation included the Modified Ashworth Scale for spasticity, Barthel Index for daily living activities, and the 10-Meter Walk Test. The intervention program combined physiotherapy, hydrotherapy, massage, magnetotherapy, and robotic-assisted training with ALEx RS.

Results. At the final evaluation, the patient showed reduced spasticity, improved muscle strength, coordination, gait, and independence in daily activities. The Barthel Index improved from 45 to 65 points, and the 10-Meter Walk Test improved from 25 seconds to 19 seconds.

Conclusions. The use of ALEx RS combined with complementary therapies contributed to significant improvements in motor function, mobility, and quality of life. This case study highlights the role of robotic-assisted rehabilitation as an effective tool in post-stroke therapy.

Keywords: stroke, rehabilitation, robotic exoskeleton, ALEx RS, physiotherapy.

Introduction

The development of the Arm Light Exoskeleton Rehab Station (ALEx RS) for post-stroke upper limb mobility recovery reflects an increasing recognition of the importance of innovative rehabilitation technologies in enhancing patient outcomes. The application of exoskeleton technology in stroke rehabilitation demonstrates potential not only in restoring mobility but also in improving overall functioning and quality of life for stroke survivors (Meng et al., 2019; (Louie et al., 2021). The ALEx RS is designed to assist patients in performing rehabilitation exercises that enhance the mobility of the shoulder, elbow, and forearm, featuring a user-centered design that accommodates the anatomical movements required for upper limb rehabilitation (Wahyu et al., 2023; Rico et al., 2016).

The exoskeleton's mechanical design aims to maximize freedom of movement while ensuring user comfort, which is crucial for sustained rehabilitation activity (Wahyu et al., 2023; Li et al., 2024). The inclusion of flexible fabric and a lightweight framework minimizes the physical burden on users, facilitating longer durations of use during therapeutic sessions (Jin et al., 2024). This design philosophy aligns with contemporary approaches that reduce user fatigue through ergonomic principles, essential for maintaining patient engagement in rehabilitation exercises (Louie et al., 2020; Vaughan-Graham et al., 2020). Moreover, incorporating various actuation methods ensures a range of motion that can adapt to the specific rehabilitation needs of different recovery stages, as outlined in common rehabilitation models for stroke therapy (Manna & Dubey, 2019).

Research has indicated that intensive, adaptive therapy significantly accelerates recovery in post-stroke patients (Manna & Dubey, 2019; Louie et al., 2021). Devices such as the ALEx RS can provide necessary sensory feedback, often lacking in conventional rehabilitation methods, thereby fostering motor skill learning and enhancing motivation (Manna & Dubey, 2019; Tang et al., 2023). Studies highlight that using technology to provide real-time feedback improves neuroplasticity, which is vital for restoring motor function (Tang et al., 2023; Rico et al., 2016). The integration of exoskeletons not only addresses the physical aspects of rehabilitation but also engages patients cognitively and emotionally in their recovery processes (Vaughan-Graham et al., 2020; Louie et al., 2021).

In terms of clinical efficacy, recent meta-analyses have demonstrated that powered exoskeletons can significantly improve upper limb functionality in stroke survivors (Kim & Kim, 2022; Norouzi-Gheidari et al., 2012). Exoskeletons like the ALEx RS allow for repeated task practice, linked to better functional outcomes compared to conventional

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therapy (Louie et al., 2020; Hobbs & Artemiadis, 2020). Early results suggest that patients who engage with robotic systems experience greater improvements in muscle strength and coordination (Meng et al., 2019; Louie et al., 2021). This supports the notion that exoskeletons can effectively augment traditional rehabilitation protocols, enabling patients to engage in higher volumes of practice than would otherwise be feasible with human therapists alone (Kim & Kim, 2022; Maciejasz et al., 2014).

Kinematic analysis is another critical component in the design and application of the ALEx RS. The exoskeleton features joints that effectively replicate human movement patterns, essential for producing naturalistic motions during rehabilitation (Manna & Dubey, 2019; Pang et al., 2020; Rico et al., 2016). This biomechanical fidelity ensures that patients gain functional skills transferable to their daily activities post-rehabilitation (Sarhan et al., 2024; Zhang et al., 2020). Careful consideration of mechanical design can lead to devices that not only assist in motion but also promote muscle strength and adaptability over time (Rahman et al., 2014; Zhang et al., 2015).

Additionally, integrating feedback and control mechanisms such as electromyography (EMG) can offer a tailored experience for patients. By utilizing EMG signals to control exoskeleton movements, the ALEx RS can adapt in real-time to the user's physiological responses, providing a more immersive and effective rehabilitation environment (Jin et al., 2024; Triwiyanto et al., 2023; Tang et al., 2023). This approach is particularly beneficial for patients who demonstrate varying recovery progress levels, allowing for personalized training regimens that adjust to their specific functional capacities during different rehabilitation sessions (Tang et al., 2023; Maciejasz et al., 2014).

Research has also highlighted the potential psychological benefits of using exoskeletons in rehabilitation settings. The empowerment experienced by patients when using these devices can lead to heightened motivation and satisfaction, critical components of a successful recovery journey (Vaughan-Graham et al., 2020; Fernández et al., 2021; Zhang et al., 2024). Patient perspectives outlined in qualitative studies underscore the importance of incorporating user feedback into the design process to ensure that technological interventions are effective and acceptable to end-users (Triwiyanto et al., 2023; Vaughan-Graham et al., 2020; Louie et al., 2021).

Integrating the Arm Light Exoskeleton Rehab Station (ALEx RS) into post-stroke rehabilitation represents a multidisciplinary approach that harnesses advancements in robotics, biomechanics, and neurorehabilitation principles. Such innovations are poised to revolutionize recovery strategies, making therapy more efficient, effective, and tailored to the unique needs of stroke survivors. Ongoing research and clinical trials will be pivotal in validating the long-term benefits of these emerging technologies and their role in restoring autonomy and quality of life to individuals affected by stroke.

Objectives

The primary objective of this case study was to explore the effects of an integrated rehabilitation program that combined conventional physiotherapy with robotic-assisted training using the ALEx RS exoskeleton. More specifically, the rehabilitation approach aimed to enhance the patient's muscle strength and endurance in the affected upper and lower limbs, while at the same time maintaining and improving joint mobility. Another important objective was to improve postural stability and balance, thereby reducing the risk of falls and facilitating greater independence in daily activities.

A further focus was placed on reducing spasticity and improving neuromuscular coordination, as these elements are essential for restoring functional movements of the upper limb. Finally, the rehabilitation program sought to promote gait re-education and to increase the patient's overall autonomy in personal care and daily living tasks. Through these objectives, the study intended to demonstrate how a patient-centered, technologically assisted therapeutic program can contribute to functional recovery and an improved quality of life after stroke.

Methods

The study was conducted over a 12-week period at the Techirghiol Balneal and Recovery Sanatorium in Constanța. The subject was a 71-year-old male with a medical history of arterial hypertension and right hemispheric ischemic stroke, resulting in left spastic hemiparesis.

Clinical assessment included:

- Modified Ashworth Scale for spasticity;
- Barthel Index for activities of daily living;
- 10-Meter Walk Test for gait performance.

The rehabilitation program included physiotherapy, hydrokinetotherapy, massage, magnetotherapy, and robotic-assisted rehabilitation using ALEx RS. Exercises involved passive and active movements, bilateral mirror therapy, and guided assistance. The ALEx RS exoskeleton supported flexion–extension and abduction–adduction movements, enhancing neuromotor re-education.

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Results

At the end of the 12-week rehabilitation program, the patient demonstrated significant functional improvements. Muscle strength in the left upper and lower limbs increased, coordination improved, and balance deficits diminished. Spasticity decreased according to the Modified Ashworth Scale, and the patient showed greater independence in daily activities.

Table 1. Evolution of motor function and daily living capacity

Parameter	Initial Evaluation	Final Evaluation	Outcome
Muscle strength – left arm	Low	Improved	↑ Functional use
Muscle strength – left leg	Low	Improved	↑ Stability
Coordination – left arm	Limited	Improved	↑ Motor control
Coordination – left leg	Limited	Improved	↑ Gait quality
Balance	Deficient	Improved	↓ Fall risk
Barthel Index	45	65	↑ Independence
10-Meter Walk Test (sec)	25 sec (Score 0)	19 sec (Score 5)	↑ Walking speed

The improvements observed were clinically relevant, as the patient progressed from limited mobility and dependence to improved functional capacity. The reduction in walking time by six seconds at the 10-Meter Walk Test indicated a measurable gain in gait efficiency. Similarly, the increase of 20 points in the Barthel Index demonstrated a substantial enhancement in the patient's ability to perform daily living activities independently.

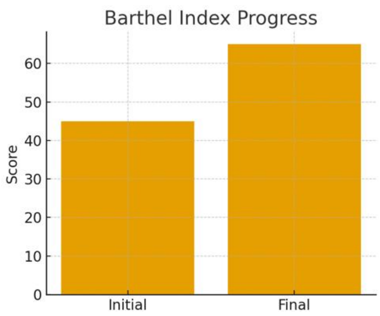

Figure 1. Progress in Barthel Index

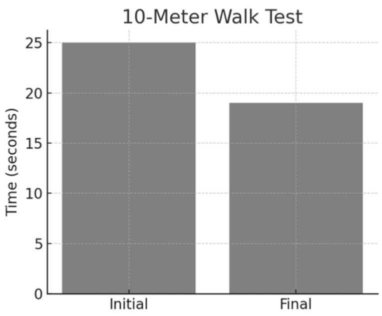

Figure 2. Progress in 10-Meter Walk Test Score

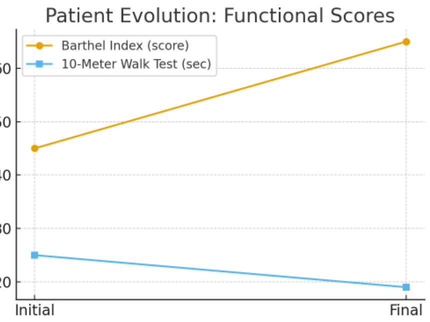

Figure 3. Patient Evolution: Functional Scores

Discussions

The findings of this case study highlight the benefits of integrating robotic-assisted rehabilitation with conventional physiotherapy in post-stroke recovery. The patient demonstrated significant improvements in muscle strength, coordination, gait, and daily living independence after a 12-week intervention. These results are in line with recent literature emphasizing the value of exoskeleton technologies in enhancing neurorehabilitation outcomes.

Previous studies have demonstrated that robotic exoskeletons provide high-intensity, repetitive, and task-oriented training that is crucial for stimulating neuroplasticity and functional recovery (Meng et al., 2019; Louie et al., 2021). The improvements observed in this patient, such as reduced spasticity and improved Barthel Index scores, support the findings of meta-analyses that report superior functional outcomes when robotic systems are integrated into rehabilitation compared to conventional therapy alone (Kim & Kim, 2022; Norouzi-Gheidari et al., 2012).

The design of the ALEx RS, which emphasizes biomechanical fidelity and ergonomic comfort (Wahyu et al., 2023; Rico et al., 2016; Li et al., 2024), may have contributed to the patient's ability to sustain therapy sessions without excessive fatigue. This aligns with contemporary approaches that reduce user burden and promote adherence to long-term rehabilitation (Vaughan-Graham et al., 2020).

The kinematic precision of ALEx RS allows for naturalistic and symmetrical upper limb motions, consistent with other devices that replicate physiological joint movements to support functional skill transfer (Pang et al., 2020; Zhang et al., 2020). Furthermore, evidence suggests that incorporating adaptive control mechanisms, such as real-time feedback or electromyography (EMG)-based systems, enhances the personalization and efficacy of robotic-assisted therapy (Tang et al., 2023; Jin et al., 2024; Triwiyanto et al., 2023).

In addition to physical improvements, the literature highlights the psychological and motivational advantages of robotic rehabilitation. The patient's increased engagement and autonomy observed in this study reflect similar findings reported in qualitative research, where exoskeleton use was associated with heightened motivation and satisfaction (Fernández et al., 2021; Vaughan-Graham et al., 2020).

These findings also emphasize the importance of combining technological innovations with individualized rehabilitation strategies. While robotic-assisted therapy provides consistency and intensity, the human component of physiotherapy remains crucial for addressing the patient's unique functional and psychological needs. The integration of ALEx RS into a multidisciplinary program allowed for the reinforcement of motor learning, which is consistent with modern neurorehabilitation principles.

The patient's functional gains were clinically meaningful: the Barthel Index increased from 45 to 65 points, indicating a transition from moderate to mild dependence in daily living activities, and the 10-Meter Walk Test improved from 25 seconds to 19 seconds, reflecting a measurable gain in walking efficiency and safety. Improvements in balance and coordination further reduced fall risk and enhanced autonomy. These results underscore the potential of robotic exoskeletons to achieve not only statistical significance but also real-world, practical benefits for stroke survivors.

Finally, this study highlights the need for larger controlled trials to confirm the long-term clinical efficacy of ALEx RS and to identify the patient populations most likely to benefit from this technology.

Conclusions

This case study demonstrates that the integration of robotic-assisted rehabilitation with conventional physiotherapy can produce significant improvements in post-stroke motor function, mobility, and independence. The use of the Arm Light Exoskeleton Rehab Station (ALEx RS) enabled repetitive, task-specific, and adaptive training that facilitated neuroplasticity and functional recovery in the patient.

The outcomes observed, including reduced spasticity, enhanced muscle strength, and improved Barthel Index scores, are consistent with evidence from recent studies showing the efficacy of robotic devices in stroke rehabilitation (Meng et al., 2019; Kim & Kim, 2022; Norouzi-Gheidari et al., 2012). Furthermore, the ergonomic and biomechanical design of ALEx RS, which emphasizes comfort and naturalistic motion patterns (Rico et al., 2016; Wahyu et al., 2023), supported patient adherence to therapy and maximized the therapeutic benefit.

While the findings are limited to a single case, they highlight the potential of exoskeleton technology to augment conventional treatment protocols and to address both the physical and psychological dimensions of recovery. Future clinical research with larger cohorts and controlled trials will be essential to validate the long-term benefits of ALEx RS and similar devices in post-stroke rehabilitation.

ALEx RS represents a valuable addition to the multidisciplinary toolkit for neurorehabilitation, offering personalized, intensive, and motivating therapy that can enhance patient outcomes and contribute to the restoration of autonomy and quality of life in stroke survivors.

References

Fernández, A., Lobo-Prat, J., & Font-Llagunes, J. (2021). Systematic review on wearable lower-limb exoskeletons for gait training in neuromuscular impairments. *Journal of Neuroengineering and Rehabilitation*, 18(1). https://doi.org/10.1186/s12984-021-00815-5 .

Hobbs, B. and Artemiadis, P. (2020). A review of robot-assisted lower-limb stroke therapy: unexplored paths and future directions in gait rehabilitation. *Frontiers in Neurorobotics*, 14. https://doi.org/10.3389/fnbot.2020.00019 .

Jin, X., Ding, W., Baumert, M., Wei, Y., Li, Q., Yang, W., … & Yan, Y. (2024). Mechanical design, analysis, and dynamics simulation of a cable-driven wearable flexible exoskeleton system. *Technologies*, 12(12), 238. https://doi.org/10.3390/technologies12120238 .

Kim, C. and Kim, H. (2022). Effect of robot-assisted wearable exoskeleton on gait speed of post-stroke patients: a systematic review and meta-analysis of a randomized controlled trials. *Physical Therapy Rehabilitation Science*, 11(4), 471-477. https://doi.org/10.14474/ptrs.2022.11.4.471

Li, K., Zhao, Y., Zhao, Y., Cui, H., Han, Z., & Zhao, L. (2024). Mechanical design and kinematic performance of an anthropomorphic shoulder rehabilitation exoskeleton. *Proceedings of the Institution of Mechanical Engineers Part C Journal of Mechanical Engineering Science*, 238(21), 10287-10302. https://doi.org/10.1177/09544062241264263.

Louie, D., Mortenson, W., Durocher, M., Schneeberg, A., Teasell, R., Yao, J., … & Eng, J. (2021). Efficacy of an exoskeleton-based physical therapy program for non-ambulatory patients during subacute stroke rehabilitation: a randomized controlled trial. *Journal of Neuroengineering and Rehabilitation*, 18(1). https://doi.org/10.1186/s12984-021-00942-z .

Louie, D., Mortenson, W., Durocher, M., Teasell, R., Yao, J., & Eng, J. (2020). Exoskeleton for post-stroke recovery of ambulation (exstra): study protocol for a mixed-methods study investigating the efficacy and acceptance of an exoskeleton-based physical therapy program during stroke inpatient rehabilitation. *BMC Neurology*, 20(1). https://doi.org/10.1186/s12883-020-1617-7 .

Maciejasz, P., Eschweiler, J., Gerlach-Hahn, K., Jansen-Troy, A., & Leonhardt, S. (2014). A survey on robotic devices for upper limb rehabilitation. *Journal of Neuroengineering and Rehabilitation*, 11(1). https://doi.org/10.1186/1743-0003-11-3

Manna, S. and Dubey, V. (2019). A portable elbow exoskeleton for three stages of rehabilitation. *Journal of Mechanisms and Robotics*, 11(6). https://doi.org/10.1115/1.4044535.

Manna, S. and Dubey, V. (2019). Rehabilitation strategy for post-stroke recovery using an innovative elbow exoskeleton. *Proceedings of the Institution of Mechanical Engineers Part H Journal of Engineering in Medicine*, 233(6), 668-680. https://doi.org/10.1177/0954411919847058.

Meng, Q., Xie, Q., Haicun, S., Cao, W., Wang, F., Wang, L., … & Li, S. (2019). Pilot study of a powered exoskeleton for upper limb rehabilitation based on the wheelchair. *Biomed Research International*, 1-11. https://doi.org/10.1155/2019/9627438.

Norouzi-Gheidari, N., Archambault, P., & Fung, J. (2012). Effects of robot-assisted therapy on stroke rehabilitation in upper limbs: systematic review and meta-analysis of the literature. T*he Journal of Rehabilitation Research and Development*, 49(4), 479. https://doi.org/10.1682/jrrd.2010.10.0210.

Pang, Z., Wang, T., Wang, Z., Yu, J., Sun, Z., & Liu, S. (2020). Design and analysis of a wearable upper limb rehabilitation robot with characteristics of tension mechanism. *Applied Sciences*, 10(6), 2101. https://doi.org/10.3390/app10062101 .

Rahman, M., Rahman, M., Cristobal, O., Saad, M., Kenné, J., & Archambault, P. (2014). Development of a whole arm wearable robotic exoskeleton for rehabilitation and to assist upper limb movements. *Robotica*, 33(1), 19-39. https://doi.org/10.1017/s0263574714000034 .

Rico, Z., Lucio, J., López, F., & Cruz-Alcántar, P. (2016). Design of an exoskeleton for upper limb robot-assisted rehabilitation based on co-simulation. *Journal of Vibroengineering*, 18(5), 3269-3278. https://doi.org/10.21595/jve.2016.16857 .

Sarhan, S. M., Al-Faiz, M. Z., & Takhakh, A. (2024). Eeg-based control of a 3d-printed upper limb exoskeleton for stroke rehabilitation. *International Journal of Online and Biomedical Engineering* (Ijoe), 20(09), 99-112. https://doi.org/10.3991/ijoe.v20i09.48475.

Tang, Z., Wang, H., Cui, Z., Jin, X., Zhang, L., Peng, Y., … & Xing, B. (2023). An upper-limb rehabilitation exoskeleton system controlled by mi recognition model with deep emphasized informative features in a vr scene. *Ieee Transactions on Neural Systems and Rehabilitation Engineering*, 31, 4390-4401. https://doi.org/10.1109/tnsre.2023.3329059 .

Triwiyanto, T., Caesarendra, W., Abdullayev, V., Ahmed, A., & Herianto, H. (2023). Single lead emg signal to control an upper limb exoskeleton using embedded machine learning on raspberry pi. *Journal of Robotics and Control* (Jrc), 4(1), 35-45. https://doi.org/10.18196/jrc.v4i1.17364.

Vaughan-Graham, J., Brooks, D., Rose, L., Nejat, G., Pons, J., & Patterson, K. (2020). Exoskeleton use in post-stroke gait rehabilitation: a qualitative study of the perspectives of persons post-stroke and physiotherapists. *Journal of Neuroengineering and Rehabilitation*, 17(1). https://doi.org/10.1186/s12984-020-00750-x.

Wahyu, E., Sumartini, S., Widyo, P., & Herdiman, L. (2023). Exoskeleton design using kinematics analysis for upper limb rehabilitation in post-stroke patients. *E3s Web of Conferences*, 465, 02027. https://doi.org/10.1051/e3sconf/202346502027 .

Zhang, F., Fu, Y., Zhang, Q., & Wang, S. (2015). Experiments and kinematics analysis of a hand rehabilitation exoskeleton with circuitous joints. *Bio-Medical Materials and Engineering*, 26(1_suppl), S665-S672. https://doi.org/10.3233/bme-151358 .

Zhang, J., Yao, J., Wang, T., Zhao, Q., & Qi, Q. (2020). Impacts of a lower limb exoskeleton robot on anxious stroke patients. *E3s Web of Conferences*, 218, 03050. https://doi.org/10.1051/e3sconf/202021803050.

Zhang, Y., Zhao, W., Wan, C., Wu, X., Huang, J., Wang, X., … & Li, Y. (2024). Exoskeleton rehabilitation robot training for balance and lower limb function in sub-acute stroke patients: a pilot, randomized controlled trial. *Journal of Neuroengineering and Rehabilitation,* 21(1). https://doi.org/10.1186/s12984-024-01391-0 .