The evolution of exoskeletons: From stationary devices to mobile assistants

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From Neglect and Limited Therapy to the Rise of Robotics

In the annals of medical history the treatment of neurological disorders has undergone a significant transformation. From an era when patients with such conditions were largely neglected, to the modern advancements in robotic therapy, the journey has been marked by innovation and progress. Centuries ago, patients with neurological ailments received scant attention, as medical focus primarily centered on other health conditions. Consequently, therapeutic interventions for neurological disorders were minimal. Over time, a realization dawned regarding the plasticity of the nervous system. Therapy efforts intensified, particularly targeting patients afflicted with strokes and other neurological conditions. However, a major hurdle persisted — therapy was labor-intensive, time-consuming, and financially burdensome. To address these challenges, the concept of robotic assistance in therapy emerged. The development of robotic devices aimed at enhancing gait and upper limb rehabilitation marked a significant turning point. Two categories of robots emerged: exoskeletons and endeffector-based systems, each with its unique features and challenges.

Endeffectors, Exoskeletons, and Soft Exosuits

Exoskeletons, such as the Lokomat and ARMin, provided support for complex movements but posed challenges in aligning with anatomical joint axes. Endeffector-based systems like GaitTrainer and MIT-Manus offered simplicity and cost-effectiveness but struggled with posture and movement control so that additional personal effort was necessary unless limiting the therapy to simple movements involving only one or two joints.

Recent years have witnessed the advent of mobile exoskeletons, offering newfound freedom and accessibility. Products like ReWalk and Indego, along with various prototypes, have expanded the landscape of robotic rehabilitation. Further innovation has led to the evolution of rigid exoskeletons into soft exosuits, promising enhanced comfort and affordability. The transition brings forth a debate between the advantages of stiffness for load bearing and the lightweight nature of soft exosuits. Soft exosuits, exemplified by Myosuit and

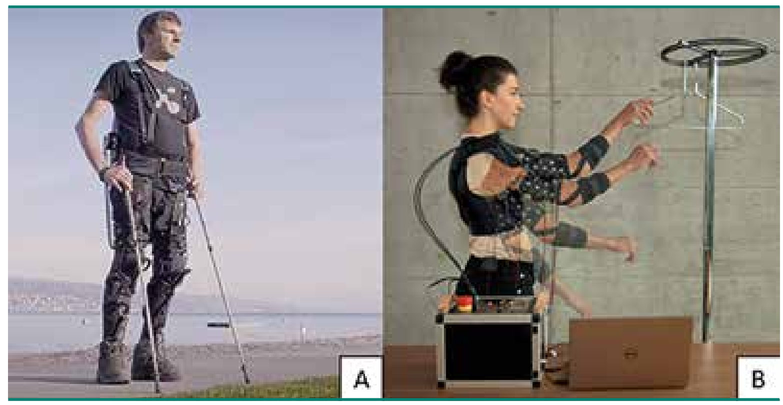

Figure 1. A) Myosuit: Patient with incomplete tetraplegia (25+ years since injury) walks without assistance wearing the Myosuit. **B)** Stability-Mobility Concept Myoshirt: Arm elevation assistance in patients with shoulder instability and muscular weakness. Source: SMS Lab. ETH Zurich

Myoshirt (see **Figure 1**), offer hope for patients with heart failure by breaking the cycle of deconditioning and dyspnea. Their application in gait rehabilitation and upper limb support further underscores their potential.

Future Horizons

As technology continues to advance, the realm of robotic rehabilitation holds promise for even more groundbreaking innovations. Concepts like therapy during sleep and vestibular stimulation hint at a future where boundaries are pushed further (see **Figure 2**). The journey

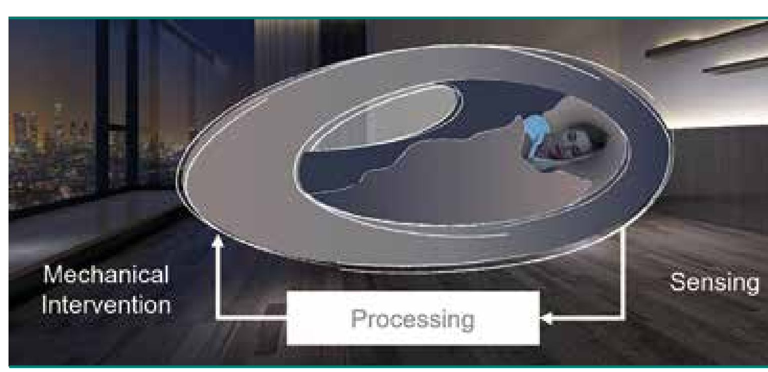

Figure 2. Somnomat Concept: Closed-loop rocking bed for treatment of patients during sleep. Source: SMS Lab, ETH Zurich

of robotic rehabilitation — from its humble beginnings to its current state of sophistication — stands as a testament to human ingenuity and the relentless pursuit of improving patient outcomes. As we stand at the cusp of a new era, the possibilities for enhancing neurological therapy through robotics are boundless.

References:

1. Crivelli F, Omlin X, Rauter G, Von Zitzewitz J, Achermann P, Riener R. Somnomat: a novel actuated bed to investigate the effect of vestibular stimulation. Medical & Biological Engineering & Computing. 2016; 54(6): 877–89
2. Grimmer M, Riener R, Walsh CJ, Seyfarth A. Mobility related physical and functional losses due to aging and disease – a motivation for lower limb exoskeletons. J NeuroEngineering Rehabil 2019; 16(2). https://doi.org/10.1186/s12984-018-0458-8
3. Klamroth-Marganska V, Blanco J, Campen K, Curt A, Dietz V, Ettlin T, et al. Three-dimensional, task-specific robot therapy of the arm after stroke: a multicentre, parallel-group randomised trial. The Lancet Neurology 2014; 13(2): 159–66
4. Riener R, Lünenburger L, Maier I, Colombo G, Dietz V. Locomotor Training in Subjects with SensoriMotor Deficits: An Overview of the Robotic Gait Orthosis Lokomat. Journal of Healthcare Engineering. 2010; 1: 197–216
5. Schmidt K, Duarte JE, Grimmer M, Sancho-Puchades A, Wei H, Easthope CS, et al. The Myosuit: Bi-articular Anti-gravity Exosuit That Reduces Hip Extensor Activity in Sitting Transfers. Frontiers in Neurorobotics 2017; 11

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