Editorial

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The increasingly important role of robots in rehabilitation

A rehabilitation robot is a service robot for professional use[1] that provides physical and information-related assistance during therapy sessions to rehabilitate sensorimotor deficits after damage to the central nervous system (CNS). The therapy is performed by stimulating physiological limb muscles and peripheral receptors through functional arm/hand and leg movement exercises based on the neuroplasticity principle[2].

Advancements in robotic technology developed based on neurophysiological and clinical insights have produced encouraging results in the healthcare field. The rehabilitation robots empower patients physically and psychologically in their recovery journey. Studies have found improved enthusiasm in patient participation through the use of engaging gaming and technology-assisted social interaction. The robot also assists rehabilitation practitioners in realising more accessible, efficient, and consistent training while collecting valuable data to assess patients' recovery progress.

The development of rehabilitation robots dates back to a 1910 patent filed by Theodor Büdingen on a 'movement cure apparatus', a machine driven by an electric motor to guide and support stepping movements in patients with heart disease. However, it was not until 1989 that commercial rehabilitation robots took to the market with the development of the MIT-MANUS, which was first tested clinically in 1994[3]. These devices can assist in activating upper or lower limb movements and motor relearning and developing proprioception, cognitive functions, and attention[4]. The emphasis has been on achieving high repetitions in interactive and self-initiated therapy to attain a higher functional recovery in a shorter time frame. The philosophy of applying robots in rehabilitation is not to replace the therapist but to widen treatment options[5].

Some of the current commercially available rehabilitation robots are for specific segments of the limbs, not the whole body; they have restricted sensory input and decision-making capabilities. For upper extremity (UE) therapy, it would be reasonable

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[1] https://ifr.org/img/office/Service_Robots_2016_Chapter_1_2.pdf

[2] Gassert, R., Dietz, V. Rehabilitation robots for the treatment of sensorimotor deficits: a neurophysiological perspective. J NeuroEngineering Rehabil 15, 46 (2018). https://doi.org/10.1186/s12984-018-0383-x.

[3] Robot-aided neurorehabilitation. IEEE Trans Rehabil Eng, v.6 (1) , p.75, 1998, Krebs HI et al.

[4] Khalili D, Zomlefer M. An intelligent robotic system for rehabilitation of joints and estimation of body segment parameters. IEEE Trans Biomed Eng. 1988;35(2):138–46.

[5] Poli P, Morone G, Rosati G, et al. Robotic technologies and rehabilitation: new tools for stroke patients' therapy. Biomed Res Int. 2013;153872. DOI:10.1155/2013/153872.

to involve at least the entire upper limb from the shoulder to the fingers because, in practice, people use these parts together in coordination for functional tasks. We can assume that moving the whole upper limb is necessary for restoring efficient inter-joint coordination.

In early mobilisation and treadmill training, gait rehabilitation robots help mobilise the patient into a vertical position, supporting the physiological gait training process and reducing secondary complications. It also provides physical support to caregivers and therapists. Patients can perform overground gait training with wearable exoskeletons as they improve. These robots can serve not only as therapeutic but also as assistive devices.

Many clinical trials and meta-analyses evaluate the efficacy of rehabilitation robots, with mixed results. For UE training, studies indicate improvement in activities of daily living (ADL), arm and hand function, and arm and hand muscle strength[6]. For lower extremity (LE) training, the Cochrane review published by Mehrholz et al[7]. suggests that post-stroke patients who received such training in combination with traditional physiotherapy were more likely to achieve independent walking than subjects who only received conventional therapy. Specifically, people in the first three months after stroke and those unable to walk benefited most from this type of intervention. These results suggest that robot-mediated therapy gives certain advantages for patients, at least in motor relearning[8].

The 2010 Stroke Care Guidelines of the American Heart Association (AHA) and the Veterans Administration/Department of Defence (VA/DoD) endorsed rehabilitation robotics for UE post-stroke care. However, the conclusion for LE robot therapy at the time was less encouraging. It states that such robot therapy is much less effective than usual care practices in the US[9]. However, newer studies have shown that a combinatory approach improves motor function in post-stroke arm paresis[10].

Treatments using rehabilitation robots enable delegating more manual and repetitive therapy components to robotic devices, allowing a clinician practitioner to take care of

[6] Mehrholz J, Pohl M, Platz T, Kugler J, Elsner B. Electromechanical and robot-assisted arm training for improving activities of daily living, arm function, and arm muscle strength after stroke. Cochrane Database Syst Rev. 2015 Nov 7;2015(11):CD006876. doi: 10.1002/14651858.CD006876.pub4. Update in: Cochrane Database Syst Rev. 2018 Sep 03;9:CD006876. PMID: 26559225; PMCID: PMC6465047.

[7] Mehrholz J, Thomas S, Kugler J, Pohl M, Elsner B. Electromechanical-assisted training for walking after stroke. Cochrane Database Syst Rev. 2020 Oct 22;10(10):CD006185. doi: 10.1002/14651858.CD006185.pub5. PMID: 33091160; PMCID: PMC8189995.

[8] Fazekas, G & Tavaszi, I (2019) The future role of robots in neuro-rehabilitation, Expert Review of Neurotherapeutics, 19:6, 471-473, DOI: 10.1080/14737175.2019.1617700

[9] Bates J et al., Rehabil Res Dev 47(9):1–43, 2010; Miller EL et al., Stroke 41(10):2402–2448, 2010

[10] Budhota A, Chua KSG, Hussain A, Kager S, Cherpin A, Contu S, Vishwanath D, Kuah CWK, Ng CY, Yam LHL, Loh YJ, Rajeswaran DK, Xiang L, Burdet E, Campolo D. Robotic Assisted Upper Limb Training Post Stroke: A Randomized Control Trial Using Combinatory Approach Toward Reducing Workforce Demands. Front Neurol. 2021 Jun 2;12:622014. doi: 10.3389/fneur.2021.622014. PMID: 34149587; PMCID: PMC8206540.

more patients in a given time and improving the accessibility of therapy for patients remotely from the comfort of their homes through telerehabilitation. The data collected can objectively assess performance and document compliance and progress using artificial intelligence (AI), promoting data-driven therapy. Virtual reality (VR), combined with haptics, offers therapists more customisable treatment options in a safe environment.

- The benefits of the adoption of rehabilitation robots are clear:
- A therapist can get an overview of the patient's progress,
- The technology is primarily automated and data-driven, and
- Significant increase in accessibility to therapy by patients.

There are still issues to be solved in rehabilitation robots and many questions to be answered, such as efficacy, costs, reimbursement, and regulatory challenges. McKinsey Global Institute mentioned that by 2040, new technologies such as robotics and exoskeletons could reduce the total disease burden by 6 to 10 per cent[11]. Manufacturers, such as Fourier Intelligence, are increasingly investing in research activities by collaborating with established rehabilitation research institutes to innovate and develop new ideas. Such collaborations will allow future rehabilitation robots to:

- Gain more sophisticated sensory input from the patient,
- Make informed therapeutic programme decisions using AI,
- Develop realistic and immersive VR exercises with haptic feedback to practice functions that are activities of daily living,
- Develop comprehensive options for home use of robots,
- Develop more options for applying robots as training devices and as assistive devices, and
- Improve the cost-benefit ratio.

[11] Rames et al. (2020) Ten Innovations that can improve global health. https://www.mckinsey.com/industries/healthcare-systems-and-services/our-insights/ten-innovations-that-can-improve-global-health

Figure 1 RehabHub™ concept addressed rehabilitation robots' affordability, accessibility, and adaptability in clinical settings.

With the introduction of the RehabHub™ (Figure 1) concept in 56 countries, Fourier Intelligence addressed the affordability, accessibility, and adaptability of rehabilitation robots in clinical settings. Robotic technology is offered as a resource to help reduce the physical burden of therapists and improve efficiency in therapy sessions. Clinical trials suggest that current rehabilitation robots can provide certain advantages for patients. Studies have also identified further potentials to be delivered by rehabilitation robots through future technical development. In the long-term, this will bridge the skills gap, meet the ever-increasing need for rehabilitation services and, ultimately, improve the quality and efficiency of the overall health care system.