CONTENT

Using robotic-assisted technology to improve lower-limb function in people with stroke

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Abstract

Robotic-assisted gait training is becoming an important component of the rehabilitation strategy when working with patients diagnosed with a stroke. To date, research has largely focused on the effect of using robotic-assisted devices on lower limb function through the assessment of gait and balance parameters in sub-acute and chronic stroke patients, in a clinical setting. However, there may be significant benefit of implementing robotic-assisted gait training devices in the acute hospital setting soon after stroke diagnosis, but also with chronic stroke patients as a home-based rehabilitation tool. This article concludes that further research is needed when considering the influence of robotic-assisted technology on the early mobilisation (*i.e.*, ability to stand and walk with and/or without the support from a therapist) of stroke patients in the hospital setting, their implementation in a home-based environment, and the need to incorporate more robust, quantifiable and scientific techniques to evaluate stroke patient progress through a variety of biomechanical assessment parameters.

Key words: robotics; stroke; rehabilitation; early mobilisation

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Introduction

Stroke is a leading cause of adult neurologic disability causing significant physical and cognitive impairments. Seventeen million people worldwide have a stroke of which one third will die and one third will be left permanently disabled. As medical care and treatment techniques improve, survival rates are ever increasing.[1] This equates to an increasing population with stroke-related disability who experience limitations in communication, activities of daily living, and mobility. A large majority of this population ranks improving their ability to walk among their top rehabilitation goals; furthermore, the ability to walk is a determining factor as to whether an individual is able to return home after their stroke. However, 30 to 40% of stroke survivors have limited or no walking ability even after rehabilitation and so there is an ongoing need to advance the efficacy of rehabilitation for stroke survivors.[2] New technologies, early discharge after intensive training, and home rehabilitation are among the innovations proposed to increase rehabilitation efficacy for stroke patients.[3] This article will consider three important research considerations surrounding the implementation of robotic-assisted technology on lower limb function in individuals with stroke, including i) early mobilisation, ii) home-based applications, and iii) incorporation of biomechanical assessments.

Early Mobilisation and Robotic-assisted Devices

Early mobilisation for stroke patients is a key research priority according to the National Institute for Health and Care Excellence.[4] Regaining post-stroke mobility is also a primary goal for the stroke patient. Motor recovery after stroke is most rapid within the first 10 weeks post-stroke and plateaus 3- to 6-months after onset.[5] It has been shown that earlier, more intensive mobilisation after stroke, may fast-track a patient's return to unassisted walking, improve functional recovery, and decrease hospital stay for patients. Therefore, effective early mobilization (*e.g.*, sitting, standing, walking) aids recovery post-stroke by reducing the disability during the years that follow.[4,6] This is important when considering that approximately 50% of patients with stroke leave the rehabilitation hospital in a wheelchair, < 15% are able to walk indoor without aids, < 10% are able to walk outdoor, and < 5% are able to climb stairs.[7] It has been established that immobility and/or bed rest is associated with long-term disability and a prolonged hospital stay. NICE and the Royal College of Physician (RCP) guidelines recommend that people with stroke should have at least 45 minutes of daily inpatient physiotherapy, involving intensive, repetitive and task-specific practice.[4,6] However, the costs associated with inpatient stroke stays are high, and inpatient stroke patients rarely meet the NICE rehabilitation recommendations (the median number of minutes per day on which physiotherapy is actually received is 35 minutes [Upper Quartile = 44.7 minutes; Lower Quartile = 27.5 minutes]).[8] Furthermore, between one and four physiotherapists are routinely needed to support patients during inpatient rehabilitation, thus, new rehabilitation approaches which require fewer hospital resources are needed to help alleviate the strain.

Robotic rehabilitation may stimulate neuroplasticity through facilitating intensive, repetitive, and task-specific practice that could enhance functional and motor performances.[9] Neuroplasticity is when there are changes to the central nervous system as a result of functional and structural processes which may occur spontaneously and/or be induced by repetitive movement practice.[10] Neuroplasticity occurs at synapses and involves molecular changes in cell signaling pathways and neurotransmission.[10] It can lead to recovery mechanisms and functional adaptations resulting from global changes in neuronal organization. It is associated with changes in excitatory/inhibitory balance as well as the spatial extent and activation of cortical maps and structural remodeling. Lower-limb robotic technology may increase stability and actively engage the affected leg during functional tasks, enabling patients to undertake more repetitions of specific tasks than when not wearing such devices. The application of robotic devices within physiotherapy may therefore, over time, elicit greater sensorimotor and cerebellar activation, and thus provide the therapist with a wider choice of options for delivering movement rehabilitation grounded on the principles underpinning neuroplasticity in the human central nervous system.[10] Not only may this improve functional outcomes for the patient, it could potentially reduce the number of therapists needed to support patients in the acute hospital setting thus, reducing healthcare costs.

Lower-limb rehabilitation robots have been developed to enhance the motor function of paralyzed limbs in stroke patients. A recent systematic review demonstrated that with chronic stroke patients (> 3 months post-stroke), robotic training produced better outcomes than usual-care training/therapy for individuals with severe lower limb impairment.[11] The authors demonstrated that in five out of the 10 included in the systematic review, robotic training elicits significantly more effective changes in Functional Ambulation Classification scores, an indicator of walking ability, than usual care control participants.[11] A Cochrane Review entitled: 'automated training devices for improving walking after stroke' showed that 33 of the 36 included studies recruited stroke patients at least 1-month post-stroke, with some studies recruiting patients up to 7 years post-stroke.[12] The only two studies to recruit acute stroke patients (within 15 days of stroke onset), 8 to 12 days post-stroke, concluded that early, intensive use of an automated gait trainer in an acute hospital setting improved walking ability over-and-above conventional treatment, and that lower extremity robotics is well-tolerated and improves ankle motor control and gait patterns.

The implementation of robotic-assisted devices in the acute hospital setting could potentially increase efficiency and cost-effectiveness by reducing the labour-intensive aspects of physical rehabilitation (*e.g.*, reducing staff costs), decreasing the time to achieve mobilisation milestones (*i.e.*, initiating sitting-balance, standing-balance and walking within 24 to 72 hours post-stroke), leading to earlier hospital discharge and improving functional outcomes (walking, balance) with demonstrable patient benefit, as shown in other clinical settings.[12] The use of robotic-assisted technologies for early mobilization and the acceptability of such devices, is yet to be examined within the acute hospital setting, where greater short- and longer-term benefits could be achieved than conventional, usual care, physiotherapy. Furthermore, if the application of robotic technology can improve functional and mobilization outcomes, this may reduce the suffering, and the financial and psychosocial burden of stroke on the individual, family, and society. It may also improve patient confidence and self-esteem by allowing the individual to re-engage in physical and social activities.

Home-based Applications with Robotic-assisted Devices

When considering the literature with chronic stroke patients, it is important to remember gait and balance problems can persist through the chronic stages of the condition.[13] Although individuals with stroke often receive some rehabilitation during the acute and sub-acute phases, rarely does rehabilitation extend beyond 12 months post-injury due to a lack of resources for long-term services.[13] Individuals living with the effect of stroke perceive access to therapy support, beyond the inpatient hospital stay, to be limited. It has been reported that 43% of stroke survivors want additional therapy support following inpatient hospital discharge, while 29% of patients want more services.[14] As well as implementation of robotic-assisted devices in the acute stages of stroke pre-discharge, these devices could potentially increase resources to fulfil these long-term demands through clinician's providing the preliminary training to use such a device independently at home enabling the clinician to implement rehabilitation without physically being present.[15]

We can divide robot-assistive gait training (RAGT) devices into two main classifications; static and dynamic.[3] Static RAGT is where the patient is moved in a fixed place, while dynamic RAGT moves the patient around the environment. The most common static devices are exoskeleton robots and end-effector robots. Treadmill-based exoskeleton robots use a harness-supported body weight system in conjunction with a treadmill, with the Lokomat, LokoHelp, BLEEX, and LOPES cited in the literature. End-effector robots is where a patient's feet are secured to footplates which symmetrically generate stance and swing phases during gait rehabilitation.[16] Static RAGT have been extensively investigated and are perhaps most efficacious with non-ambulatory populations.[17] For example, clinical experimental studies with the LokoHelp have proved that the rehabilitation effect of the robot system is almost the same as that of the traditional gait training method, but it significantly reduces the required human resources and the physical exertion of the participants. However, these devices are large, restricted to a clinical setting, space consuming, expensive, typically non-portable and require significant technical support to control and program the RAGT.

Many studies support the argument in favour of advantages gained by robot-assisted therapies, however integration of these technologies for home use has been very slow. Some dynamic over ground gait trainers can be bulky, and mobile systems still lack long duration power supply solutions, but allows the user to walk independently across ground at their own pace and under their own control, within the home. It is a general recommendation across national stroke guidelines that patients should undergo as much therapy as appropriate to their needs and as much as they are willing and able to tolerate. The use of dynamic devices around the home allows the patient to gain as much intensity of training as they can manage, also allowing neglected populations such as those unable to travel or in residential or nursing homes, to gain some level of rehabilitation within the home. It allows patients to perform repetitive tasks independently, not replacing the therapist, but supporting the therapy program. It has been demonstrated that home-based rehabilitation is superior to centre-based rehabilitation for functional benefits, as measured by the Barthel Index, in the early period post-discharge.[18] This highlights the importance of considering home-based rehabilitation provision more readily, whether increasing physical therapy or using robotic devices within the home. As health care delivery shifts away from traditional hospital settings and increasingly into the community, there is a growing need and interest in the feasibility and efficacy of these home-based robotic interventions to prove their potential capabilities in a home-based setting. Research from our laboratory has demonstrated some provisional yet encouraging evidence supporting the effect of implementing RAGT in a home-based environment on vascular, functional, psycho-social and biomechanical outcomes.[19]

Assessing Biomechanical Effects of Robotic Devices

Randomized control trials have shown the effectiveness of RAGT on functional and motor outcomes in patients after stroke.[20] The majority of research conducted on RAGT have relied on more traditional clinical assessments to assess both balance and walking ability, each of which presents their own set of limitations. Assessment tools have been developed specifically for quantifying the effects of stroke such as the Chedoke-McMaster Stroke Assessment and the Fugl-Meyer test. In many respects, these scales often include a mix measurement of impairment and disability. Many stroke rehabilitation assessment protocols are "standardized and validated," but most rely on an examiner, typically the treating clinician, to make judgments regarding the patient's performance. Patient walking and functional ability is usually quantified by employing clinical measures such as the Barthel index and Dynamic Gait Index. These measures are a useful tool for therapists to form an idea of ability, however do not have the capability to comprehensively identify very specific areas of improvement after interventions. Some studies look at more in depth biomechanical parameters such as walking speed and step length which has been shown to improve after a static RAGT training program.[21] Other biomechanical parameters reported are the single leg stance or swing time of the impaired limb which tends to be expressed as percentage of the gait cycle duration.[19] Few studies look at more detailed kinematic and kinetic parameters at baseline and post intervention with RAGT devices to track detailed changes. One study provided a comprehensive review of biomechanical parameters within patients with stroke after an exercise intervention including body weight supported treadmill training. Parameters included peak lower limb joint angles, moments and power during walking, however the implications of the findings were limited due to the small sample size (n = 15) impacting upon the studies statistical significance.[22] This type of analysis gives a more rounded, quantitative look at exactly where improvements may lie when researching effects of lower limb rehabilitation therapies.

The Berg Balance scale and Tinetti test are frequently used to look at balance, however laboratory-based postural sway tests should be combined with such clinical evaluations to determine balance improvements.[23] There is a need to develop standard protocols and procedures to obtain reliable objective assessment data. Alongside this, there is a lack of quantitative research supporting the improvements made with interventions using robotic devices beyond the more basic clinical assessments of walking speed and step length. Ultimately, better assessment methods may be required to truly demonstrate the advantages of applying new rehabilitation strategies, such as RAGT, within a home-based environment.

Conclusion

In conclusion, when considering the positive effects that have been reported when using lower-limb robotic-assisted technology with stroke patients, and the importance placed on early mobilisation by NICE and RCP,[1,4,5] there may be substantial patient benefit in using robotic-assisted technology within the acute hospital setting (initiating within 24 to 72 hours post-stroke), to improve patient- (*e.g.*, mobilisation milestones) and hospital outcomes (*e.g.*, physiotherapist number and time spent with patients). Furthermore, when considering the long-term disability of stroke, further research is needed to examine the efficacy of home-based rehabilitation programmes with RAGT. The inclusion of biomechanical assessments for both gait and balance should be considered in such settings as we seek to understand the benefit of RAGT on functional outcomes in individuals living with stroke.

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