USE OF ASSISTIVE TECHNOLOGY DEVICES IN REHABILITATION OF PATIENTS WITH POST-STROKE HEMIPARESIS

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Abstract:

Introduction: Stroke is one of the leading causes of death and prolonged severe disability in the elderly population. Recovery of patients after stroke hemiparesis is a long process that requires long-term medical care and rehabilitation to reduce the effects of neurological damage and motor deficits and to increase functional activity and achieve independence in performing activities of daily living. In practice, conventional methods of rehabilitation (active and passive therapeutic exercises, techniques for neuromuscular reeducation and occupational therapy) are increasingly combined with assistive technology devices. **The purpose** of this review report is to investigate the potential effectiveness of assistive technology devices and their benefit for more effective recovery of patients with post-stroke hemiparesis**. Materials and methods:** We conducted a review of available scientific literature at Pubmed, Google Scholar, ScienceDirect, which included randomized trials, prospective controlled trials, reports, guidelines for rehabilitation of patients after stroke. **Results and discussion:** Our review of the scientific literature showed evidence of the benefits of the inclusion of assistive technology devices in the rehabilitation of post-stroke hemiparesis. We found data indicating improvement in the upper and lower limb function, increased postural stability and benefits for gait, and as well as improvement of the recovery process. **Conclusion:** The medical use and combination of new assistive technology devices with conventional techniques for the recovery of post-stroke hemiparesis may be a potentially effective strategy for rehabilitation of patients after stroke, but research should continue to provide conclusive evidence of the benefits and effectiveness of these devices.

Key words: Post-stroke hemiparesis, Rehabilitation, Assistive technology devices, Robotic technology, Functional activity.

Introduction

Stroke is one of the leading causes of death and prolonged severe disability in the elderly population [1-3]. Recovery of patients after stroke hemiparesis is a long process that requires long-term medical care and rehabilitation to reduce the effects of neurological damage and motor deficits [4-6] and to increase functional activity and achieve independence in performing activities of daily living [7-9]. In practice, conventional methods of rehabilitation (active and passive therapeutic exercises, techniques for neuromuscular re-education and occupational therapy) are increasingly combined with assistive technology devices [11].

Stroke is the term given when we have a clinical situation in which there is an onset of rapidly developing clinical signs of focal disturbance of cerebral function, lasting more than 24 hours or leading to death, with no apparent cause other than being of vascular in origin. There are two main clinical forms of stroke; Ischemic and Hemorrhagic stroke. The ischemic type occurs when we have the formation of blood clots or other particles, which can otherwise block major blood vessels supplying blood to and from the brain such as the internal and external carotid arteries. Alternatively, we have the haemorrhagic form in which an artery in the brain leaks blood or ruptures and this rupturing of the blood vessels causes the leaking of blood into

the surrounding cerebral parenchyma leading to an increase in intracerebral pressure and thus damaging the surrounding brain tissue and cells [12].

Hemiparesis is a clinical entity in which we have a loss of strength in the arm, leg and sometimes face on one side of the body, it refers to an incomplete loss of strength and can be sub classified into spastic hemiparesis in which we have unilateral paresis with spasticity of the affected muscles and increased tendon reflexes. The various charecteristics signs associated with hemiparesis are as follows:

- Weakness
- Difficulty walking
- Loss of Balance
- Muscle fatigue
- Difficulty with co-ordination
- Inability to grasp objects and so a compromised motor system [13].

Approximately, 80% of people who experience a stroke also have some level of trouble moving one side of their body, or have weakness confined to only one side. According to the American Association of Rehabilitative Medicine, there are four sub-types of hemiparesis, which are known to exist. The first is right-sided hemiparesis in which the involved injury is to the left side of the person's brain and the individual who is suffering from this type of hemiparesis experiences difficulty with talking and understanding what others say and spatial difficulty in determining from right and left. On the contrary, left sided hemiparesis involves injury to the right side of the brain of the individual, which is responsible in controlling learning processes, behaviour, non-verbal communication, and injury to this area of a person's brain can lead to problems such as excessive talking, short attention spans, and memory problems. Ataxia is another common form of hemiparesis within stroke patients and it is whereby we have injury to the lower portion of the patient's brain and this can lead to difficulties such as walking, balance and posture. The final form is known as pure motor hemiparesis whereby it is the most common form of hemiparesis and it includes a weakness in the leg, arm, face and it is a condition in which all of these bodily parts may be equally affected or it may affect one body part more than others [14]

Set out in the Americans with Disabilities Act it is a person with a disability who has a physical or mental impairment that substantially limits one or more major life activity. There is an indicator which is used to calculate the burden of disability on an individual / economy and this is called the disability-adjusted life years' indices. Which gives a clear indication of the overall burden of disease, it is essentially a time-based measure that combines years of life lost due to premature mortality and years of life lost due to time lived in states of less than full health or years of healthy life lost due to disability. A score of One DALY represents the loss of equivalent of one year of full health. Using this, we can compare the burden of diseases that cause premature death but little disability with that of diseases that do not cause death but do cause disability [15]. According to the Centres for Disease Control and Prevention; 61 million in the US are disabled which correlates to 1 in 4 adults, 2 in 5 adults aged 65 and above have a disability and 1 in 4 women have a disability [16].

Generally, disabilities are more prevalent in least developed economies such as Africa and Cameroon. The burden of disabilities in countries like these are greater impacting on adults with disabilities as they are likely to experience more serious health problems and limited access to healthcare and rehabilitation services. In conjunction to this, there are severe economic consequences on the healthcare system and economy as a whole due to a disabled person being

treated as they are not able to work in professional roles or work very limited hours; they do not contribute greatly to the economy, however, they require social carers and extensive medical rehabilitative programs which cost a lot to the taxpayer leading to a fall in economic revenue and an increase in an economic cost as a whole. There is a bigger implication in the form of a social cost to the individual, family members as the disabled individual may suffer from a lack of confidence, lack of self-esteem, and self- worth which may require further rehabilitation thereby leading to a further economic burden on the family of the individual and healthcare system [17].

In addition to this, the main guidelines for treatment in rehabilitative medicine are as follows:

- Achieving a full physical and psychological recovery as soon as possible
- Improving the quality of life through gaining life management skills and a sense of direction and future resilience in the implementation of treatment programs
- Rebuilding social connectedness to families and community
- Finding a new valued role within the community
- Learning to understand and self-manage physical and mental health conditions to the best of the person's ability
- Assisting the person to return to safe and meaningful work at the earliest time possible to minimize further harm to physical and mental health and wellbeing through long term absence from employment
- Reducing the human and economic cost of disability for members within the medical speciality and the broader community.

Assistive rehabilitated technological methods help people with disabilities compensate, at least in part, for a limitation. The overall aim of this form of technological-assisted devices is to provide independence and decreases the need for other support. The devices can enable individuals to care for themselves, work, learn in normal learning and working environments, access information through computers and reading, participate fully in community life. The other beneficial advantage of the use of assistive technology in the rehabilitation programs for patients is they can be tailor fitted to suit the personal needs of the patient. In many instances, there are certain conditions in which the patient benefits the most from the usage and application of assistive technological devices and these are cognitive disabilities such as intellectual and learning disabilities, reading disorders. Those individuals with hearing disabilities such as hearing loss and impaired hearing, physical disabilities such as paralysis, difficulties with walking or other movement, inability to pick up or use certain objects, visual disabilities such as blindness, low vision or colour blindness and mental conditions such as PTSD and a wide range of anxiety and stress-related disorders. These aforementioned conditions utilise the simple or compound devices in the treatment of their conditions, however, we can also utilise complex rehabilitated technology whereby we conjoin the assistive device with another therapeutic form of treatment to achieve the most optimal outcome and this method is used in certain conditions such as: spinal cord injuries, traumatic brain injuries, multiple sclerosis, cerebral palsy, muscular dystrophy, spina bifida, myelopathy, progressive muscular atrophy and other associated conditions [18].

The purpose of this review report is to investigate the potential effectiveness of assistive technology devices and their benefit for more effective recovery of patients with post-stroke hemiparesis.

Materials and Methods

We conducted a review of available scientific literature at Pub Med, Google Scholar, Science Direct, which included randomized trials, prospective controlled trials, reports, guidelines for rehabilitation of patients after stroke. In the scientific articles, we searched for outcomes that included: stroke, post-stroke hemiparesis, severity of disability; recovery of function; post-stroke care, stroke rehabilitations, stroke rehabilitation guidelines; physiotherapy, devices for neurorehabilitation; assistive technology devices, robotic technology, exoskeleton; functional activity, activities of daily living; gait. We have also included a research and an analysis of conventionally applied rehabilitation approaches that may have an impact on the recovery period of patients with post-stroke hemiparesis. In addition, we made a review of innovative modern technology in the form of robotic assistive devices and whether the potential benefit outweighs the risk in implementing and using such forms of medical rehabilitation.

Results and discussion

Our review of the scientific literature showed evidence of the benefits of the inclusion of assistive technology devices in the rehabilitation of post-stroke hemiparesis. We found data indicating improvement in the upper and lower limb function, increased postural stability and benefits for gait, and as well as improvement of the recovery process. The results of this review showed that there is a positive relationship between the use of assistive technologies for rehabilitation and a reduction in the duration of the period of functional recovery in post-stroke hemiparesis.

Rehabilitation as a medical speciality is widely needed in the new modern era as it provides a focus on six major areas, which provide significant benefits to both the professional and to the patient, respectively. The first is in the prevention, recognition and management of co-morbidity like illness and medical complication, which is essentially to take responsibility from the beginning of treatment of the patient to the recovery stages and process and to undertake responsibility for any unexpected side effects or risks associated with the treatment. Another reason as to why rehabilitation is needed is through the treatment plans implemented by rehabilitative physicians it can provide the best chance and maximal efficacy in achieving maximum independence for the patient enabling their quality of life and overall status to be improved. In addition to this, the medical speciality of medical rehabilitation equips the individual maximum psychosocial coping and adaptation to their current disease or condition and rehabilitation professional can provide emotional support and comfort to the family, which can play a pivotal part in the treatment and speed of recovery of the patient. Furthermore, in many instances if a patient is suffering from a disability the secondary effects from this condition can cause a secondary disability [19] but by medical rehabilitation we can promote re-integration, including resumption of home, family, recreational and vocational activities. The medical rehabilitation profession can also prevent recurrent conditions from occurring, which is beneficial for the patient in the long term [20].

Consequently, through these different improvements which can be made we can provide various physical benefits to the patient [21] such as: an increase in physical capacity, reduction in pain, strengthening muscles, improvement in coordination, improvement in flexibility and joint mobility and reduction in swelling around the affected joints and muscles as well as improvement in gait and posture. The lifestyle benefits that stem from this are improvement in participation, decreased dependence, quicker return to work which can reduce financial burdens on the individual, their family and the healthcare system as a whole [22].

The use of robotic assisted devices can be devided into three categories namely known as: Medical, Assistive, Rehabilitative robotics. The medical robotics is a sub-domain, which involves the systems that provide support in medical processes of healing and care. The assistive robotic domains are systems, which assist patients in specific facilities [2] these types include the ability of bed transferring of patients, logical tasks and surveillance. Finally, the rehabilitation robotics cover a range of different forms of post-operative or post-injury care whereby they have a direct physical interaction with a robotic system, which will either enhance recovery or act as a replacement for loss of function [24].

Furthermore, robotic devices can also be organized into two perspectives: one from the level of physical contact or the morphology and the second, which is the role of the device whether it is recovery, or compensatory. On the perspective or looking at robotics from a morphological perspective we can sub-classify them into sub-sectors such as: Prostheses, Orthoses and rehabilitative aids [25].

Prostheses are external devices that partially or totally replace a limb. The WHO definition is any device, which is placed within the body for structural or functional purposes [26].

For the upper limbs, there are some modern alternatives, which exist including the robotic hands such as Bebionic robotic hand [27] or the Michealngelo prostheses hand [28-30]. In addition to this form of amputation replacement, robotic hand technology allows the patient to perform manual-dexterity exercises such as hand functions like grasping. To add to this, the development of internal bodily devices namely known under the term bio-robotic systems such as neural prostheses which are internally fixated devices or interfaces which register the neuronal activity of the brain and decode the cellular activity in terms of controlling signals. These devices are best used to treat conditions such as stroke, traumatic brain injury, neurodegenerative diseases [25].

Orthoses are externally placed devices, which are used in the modification of the structural and functional elements of the neuromuscular and skeletal system. They do not replace an existing limb or organ but instead replace or re-inforce its functionality. Active orthosis applies a force to the affected limb of a person through the robotic integrated elements of the device. The Tenoexo hand exoskeleton is used to assist patients in grasping tasks during physiotherapy and in other affected disorders such as eating or grooming [31].

There are also other upper limb robotic devices such [32] as electric engines, springs, electro-pneumatic actuators, hydraulic actuators or shape memory alloy fibres which are also used in a various number of robotic devices targeted for upper limb rehabilitation and motor training [25].

Rehabilitation aids includes those devices, which do not come under the name of prostheses or orthoses and instead are devices which are with a moderate level of physical contact and an example of these devices are the end-point robots which are partially in contact with the patient, an example being an InMotion system [33]. We also have a device called a Pressmatic, which is a non-wearable electro-mechanical device, which users must grab to employ [34]. In terms of the purpose of recovery of a patient, a robotic device is defined as a giving back the capability to an individual to perform a task using mechanisms previously employed. Examples of these devices are the Armeo power [35] and InMotion Arm System [36], which is used in circumstances, whereby extreme mobilization for motor training is required. On the other hand, robotic devices can be used for compensatory purposes whereby they are described as being atypical in terms of their approach to meet the requirements of the task using an alternative mechanism, which is not typically utilised [37].

In terms of upper limb training there are three conventional therapy methods which are: active, passive and assistive. Within the assistive method, the voluntary activity of the patient is required throughout the movement in the therapy at all times, whilst the robot can provide help to complete the task through either being weight focused or via the gravitational forces working against the specific limb. In the active form, the robot is used to measure movement and in the passive form, the robot executes all the work independently of the patient's response. Within these different methods, we have sub – methods which exist. The assistive method has basic assistive method and gravity compensatory method, the basic assistive method is one where the robot has the option of being programmed to constantly help or not depending on the strategy of therapy employed. On the other hand, the gravity compensatory method is where the robot only cancels the gravity force, so that the patient can focus on the purpose of the movement without having to deal with the external forces from the environment being applied [25].

The active method has three sub-methods described as: basic-active, active-assisted and resistive method. The basic-active method is where the robot is used to measure the evolution of the movement and so no external power is delivered to the patient's limb. In the active-assisted method, the assistance to complete a task is provided only when the patient is not capable of performing the movement actively and so the robot has a role of observing continuous performance, however, if the task is not completed the robot then intervenes taking full control. In the resistive method, the robot provides an opposing force to the direction of the intended movement. This is done via a damped or electric force applied in the opposite direction to the movement [25].

Within the passive method there also exist three different forms which include: basic-passive, bilateral and guided method. The basic-passive method, the system takes care of all movements independently of the patient's activity. The bilateral method involves a bimanual robot when the unimpaired limb is used as an input to control the passive movement of the affected side. Finally, the guided method includes the robot and its aim is to lead the subject when he/she deviates from the predefined path [25].

Conversely, for the lower limbs there are also robotic devices, which are employed and utilised in the rehabilitation programme of patients. The static robots allow patients to perform gait training in a fixed and confined area and examples includes the treadmill-based body weight support and where the patient only receives body weight assistance without lower limb support which are called treadmill-based exoskeleton where there are two types including the combination of body weight support and lower limb assistance by powered exoskeleton during gait and the body weight support end-effector where there is a combination of the body weight support and where only control of the patients feet are controlled [38].

The other major type is the over ground robot, where the patient is allowed to walk over ground and not be confined only to a certain area. The over ground type of robots are two types; assistive and rehabilitative devices. The aim of the assistive devices is to ensure mobility in a community type of environment whereas rehabilitative devices can be used to address the recovery of the gait function in patients with neurological injuries. The over ground exoskeleton are bilateral robots and usually their involvement requires upper limb aids to maintain balance. The use of robotics exoskeletons for gait rehabilitation guides the legs through pre-programmed gait-like patterns whilst the subject experiences near-normal proprioceptive input during limb loading. The pre-programmed walking pattern is similar to normal gait and it includes gait cycle timing, interlimb and interjoint coordination, appropriate limb loading and afferent signals [38].

In conclusion: The medical use and combination of new assistive technology devices with conventional techniques for the recovery of post-stroke hemiparesis may be a potentially effective strategy for rehabilitation of patients after stroke, but research should continue to provide conclusive evidence of the benefits and effectiveness of these devices.

Conflicts of Interest: The authors declare no conflict of interest.

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