·Special Lectures·

Walking training after stroke: improvements keeping our feet on the ground

Giovanni Morone, Augusto Fusco, Marco Iosa & Stefano Paolucci

Clinical Laboratory of Experimental Neurorehabilitation, IRCCS Santa Lucia Foundation, Rome 00179, Italy

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Correspondence

Giovanni Morone, Clinical Laboratory of Experimental Neurorehabilitation, IRCCS Santa Lucia Foundation, Via Ardeatina 306, Rome 00179, Italy

Tel: 0039-06-51501077

Fax: 0039-06-51501004

Email: g.morone@hsantalucia.it

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Abstract

Stroke is one of the principal causes of morbidity and mortality in adults in the developed world and the leading cause of disability in all industrialized countries. Rehabilitation's efforts are tended to avoid long-term impairments but the rehabilitative outcomes are still poor in particular on recovery of autonomous walking. Novel tools based on new technologies have been developed to improve walking recovery. A review of recent advances used in gait rehabilitation after stroke is showed in this document. It also examines the possible benefits of new tools used in walking recovery based on motor relearning approach: robotic devices, brain computer interface, non-invasive brain stimulators, neuroprostheses, and virtual reality.

Walking recovery in stroke patients is considered the chief goal of rehabilitation due to its relevance to patient independence, social participation and perceived quality of life [1-2]. In patients with ischemic stroke who have been admitted to rehabilitation hospitals, the recovery of some degree of ambulation typically occurs in nearly 55% of patients [1]. Furthermore, walking ability is not a mere result of locomotor patterns, but it needs acceptable cardiovascular condition and cerebellar capacity of sensori-motor integration to manage ground/environment condition reducing risk of falls and increasing ambulation efficacy [3-4]. In recent years, new rehabilitation approaches have been developed to optimize treatment, such as motor relearning programs, that it is focused on patients attention involvement with use of contex - specific motor-task and feedback to augment cortical involvement in the exercise to promote learning motor strategies and thus support recovery [5]. Task-oriented training can assist the natural pattern of functional recovery, which supports the view that functional recovery is mainly driven by adaptive strategies that compensate for impaired body functions. The increased intensity of training and the rehabilitation that should begin as soon as possible are two principles that have a widespread agreement, although there are no clear guidelines for best levels of practice [6-8]. To facilitate new restorative promising approach (i.e. motor relearning program), a good number of technologies were introduced in last decades: robots, brain computer interfaces, non - invasive brain stimulators, neuroprostheses and virtual reality. In robotic walking training, the machines support a patient's weight by placing them in a harness for both exoskeleton and end - effector devices [9]. End-effector principles are related to patient's extremities (hands or feet) placed on a specific support (foot-plates, for example), that impose specific trajectories [10]. In robotic gait training, stance and swing phases are permitted by use of the machine simulating a functional walking with the possibility to program drives or passive elements moving the limb joints. A recent update Cochrane revision of 17 trials, including 837 participants, showed that electromechanical - assisted gait training combined with physiotherapy may improve recovery of independent walking in patients after stroke [11]. However, as highlighted by Dobkin and Duncan, clinicians should not prescribe routinely robotic treatments in place of conventional therapy, especially if not in addiction to it or outside of a well - proved efficacy trial [12]. Invasive and non-invasive techniques allow the interference with the cortical excitability, promoting the brain plasticity [9]. Often, they are combined with robotic devices. Neuroprostheses are based on the principle of functional electrical stimulation (FES), and in recent years they have been used in stroke rehabilitation. A possible model of gait FES is based on a tilt sensor which measures the orientation of the shank, controlling when to turn the stimulator of tibialis anterior on and off [13]. Recent studies have demonstrated that they are effective in improving functional active movements, increasing gait velocity and endurance, preventing falls, reducing spasticity [13-16]. All these studies confirm the potentiality of using neuroprosthesis not only for correcting the foot drop in chronic phase, but also for aiding the sensorimotor relearning during rehabilitation of the subacute phase of stroke. Brain computer interfaces (BCIs) are a family of recent different devices aiming to translate measurements of brain activity into commands or messages. BCI is a system directly measuring brain activity (by EEG and functional magnetic resonance imaging [fMRI], for example) associated with the user's intent and translates the recorded brain activity into corresponding control signals for applications by means of a computer [9, 17]. BCI can be used to provide the patient with real-time feedback, to allow for passive monitoring (assessing motor intention without providing real-time feedback). Recently, EEG-based BCI was used to assess patient's engagement during robotic walking training [18-19]. Virtual reality refer to a high-end user-computer interface involving real-time stimulation and interactions of an embedded subject through multiple sensorial channels (visual and auditory, sometimes haptic), based on a synthetic environment in which the subject feels his presence [20]. Virtual reality treadmill training has been showed to improve balance and associated locomotor recovery skills in patients with stroke were better than traditional training did [21-22]. Different from pharmacology, where the efficacy of new drug is tested before its commercial release, studies about the effectiveness of these technologies often occur after their commercialization. Commercial push without an important knowledge of efficacy might lead to an overestimation of the potential benefit of this machine that might have a counter effect to increase scepticism and then lead to reduce their application. A number of studies showed the efficacy of these new technological approaches, whereas some others did not show any improvement in respect of conventional therapies. This uncertainty about efficacy, together with high purchase cost for some of these devices, some difficulties in their use by untrained staff, the absence of clear guidelines about better dosage and parameter values to select, and a somewhat diffuse scepticism by some members of the rehabilitation teams may limit the transfer of these new technologies from research laboratories to clinical settings, where patients are waiting to benefit from them [10]. A key point for the diffusion and the correct use of new advanced technology and/or new rehabilitative approaches is that we have to increase the information regarding which kind of patient or in which phase of improvement might be beneficial a certain type of treatment. For instance, in a four-year duration trail, we have identified patients more receptive to benefit from robotic gait-assisted therapy in combination with conventional rehabilitation, in particular the more severely impaired patients. In fact, less impaired ones seem to benefit most from a less constrained walking as the floor training, more similar to natural walking conditions than the robotic-assisted therapy that can constrain walking during training [23-25].

Another common misunderstanding is in considering walking robotic training as a treatment for walking recovery, whereas these machines, in our opinion, are a tool to perform a walking treatment. Machines can train patients just in some aspects of the walking re-education (i.e. intensity and repetition), whereas a walking training is a complex re-education that need more intensity.

In fact, machines with the body weight support are the condition sine qua non to perform intensive treatments, furthermore other aspects are important during walking re-education (motor control, sensorimotor integration, locomotor self awareness, cardiovascular capacity). These different aspects of the walking training are all important but in a different amount in respect to the severity of the patients and the onset time. Sometimes these machines have been perceived as substitute of therapist and his/her treatment. But these machines should be perceived as a new tool in the hands of therapists to improve the possibilities of training and hence the efficacy of their treatment.

In conclusion, walking recovery is a complex challenge for the rehabilitation. New devices with advanced technology will be an important tool to give the patients an opportunity to gain independency in daily life. This is important at the light that not all patients may have the same outcome. Following this principle, new tools will be an important chance for patients but not for all patients. In the last years, research has made some steps over, however we still need more information and consensus on the frequency, dose, timing and kind of walking training tailored on patients impairment, cardiovascular condition and management of sensory-motor information. We are making steps over but there is still a long way to go keeping our feet on the ground.

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