PM R 10 (2018) S165-S173

www.pmrjournal.org

Innovations Influencing Physical Medicine and Rehabilitation

Getting the Best Out of Advanced Rehabilitation Technology for the Lower Limbs: Minding Motor Learning Principles

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Abstract

Advanced technology, including gait-training devices, is increasingly being integrated into neurorehabilitation. However, to use gait-training devices to their optimal potential, it is important that they are applied in accordance with motor learning and locomotor training principles. In this article, we outline the most important principles and explain how advanced gait-training devices are best used to improve therapy outcome.

Introduction

Interest in advanced technology in rehabilitation has increased enormously over the last 2 decades. This can be illustrated by the fact that the search "rehabilitation AND technology" in PubMed delivered approximately 250 hits per year at the beginning of the century and more than 2500 hits in the last 2 years each. Tremendous progress has of course been made in technology in general in the last several decades. However, knowledge also has been gained on the therapeutic side in the same time span. Clinical evidence has become more available, and guidelines [1,2] have been developed that have shaped and vastly changed clinical practice from a compensation-focused approach (ie, compensatory movements for lost function are taught based on the dated assumption that the neural system is immutable) to the recovery-focused interventions (ie, aiming to induce activity-based neuroplasticity) we have today [3].

Advanced technology is increasingly being applied in everyday clinical practice, specifically in neurorehabilitation. Lately, multimodal approaches, for example, combinations of brain stimulation [4] or functional electrical stimulation [5] and robotic gait training, have shown promising results. However, when treating a patient with the help of advanced technology, it is crucial that clinicians still make decisions based on their knowledge of motor learning principles [6], biomechanics, neurophysiology, and neuroplasticity [7], and, in the case of lower extremity rehabilitation, their knowledge of locomotor training principles [8] and gait therapy in general. Only then can rehabilitation technology be used to its best potential and enable clinicians and patients to optimize therapeutic outcomes.

In this paper, we outline and discuss some of the relevant principles and explain how and when technology, specifically advanced gait trainers, can best be integrated into everyday clinical practice to optimize outcomes for our patients. We close with an example of how advanced technology can support the therapist and patient on the rehabilitation path to recovery.

Early Therapy Onset

To minimize complications and optimize rehabilitation outcome, therapy should be initiated in a very early phase after injury [9]. Strong evidence suggests, for example, that mobilization out of bed should happen on the second day (after hour 24, but before hour 48) after the onset of stroke [2]. However, because the cardiovascular system is often not yet stable at this time, verticalization can lead to potentially life-threatening syncopes. Tilt tables are used to verticalize patients safely. Tilt tables that integrate leg movements and/or functional electrical stimulation and hence induce the muscle pump will help to stabilize the cardiovascular system [10], reduce the number of syncopal episodes, and hence decrease therapy interruptions and increase

https://doi.org/10.1016/j.pmrj.2018.06.007

therapy time [11]. Such tilt tables can safely be used even in an intensive care setting [12].

Similarly, it has been shown that the biggest effect of electromechanically assisted gait training happens in the early phase after stroke onset [13]. In this early period, especially those patients who are severely affected, likely depend on considerable assistance and support. It is hence particularly challenging for therapists to assist these patients manually, and this might be the reason why the advanced technological gait trainers have the biggest advantage over manually assisted alternatives with this group of patients.

Those tilt tables with an included stepping mechanism further enable patients to train gait before training with an advanced gait-training device is possible. It has been shown that brain activity during the step-like movements on such devices exemplified by the Erigo (Hocoma AG, Volketswil, Switzerland) is very similar to the activity during overground walking [14].

In this very early phase after injury, patients are often also affected by disorders of consciousness. For safety reasons, inability to communicate pain or discomfort are contraindications for many rehabilitation devices. Nevertheless, a small number of studies have investigated the effect of advanced technology training on consciousness in this population. The majority of these studies investigated the effect of advanced robotic tilt tables and found a positive effect on consciousness and cognition [11,15]. The effect of robotic gait training on consciousness has not been studied as intensively. Lapitskaya et al [16] were unable to find an effect of a single session of robotic gait training on consciousness of individuals with severe traumatic brain injury and suspected that the reason was the severity of brain dysfunction in their patient sample.

Advanced technology such as robotic tilt tables and gait trainers should therefore be used to provide earlier training, while carefully considering all inclusion and exclusion criteria, to improve outcomes.

Practice Specificity

Task specificity or practice specificity [6] means that that the practiced task needs to be as similar as possible to the task that is to be learned. For example, cats who are trained how to stand will learn how to stand, but not to walk. Cats trained to walk will learn how to walk, but not stand [17]. Similarly, if a rat trains to learn to swim after a spinal cord injury (SCI), it will improve its position in the water and its hind limb activity, but not regain its walking function [18].

For humans with a neurologic deficit wanting to regain walking function, it is also important that they train physiological, upright walking. For many patients, specifically those with severe injuries, or those early after injury, training to walk is extremely difficult. A robotic gait trainer provides a safe and permissive environment, which allows the patient to practice walking in a task-specific manner without risk to themselves or the treating team.

Intensity and Guidance

One of the most widely accepted facts in neurorehabilitation is that high therapy intensity is crucial when trying to reach a patient's optimal recovery potential [19,20]. However, reaching high intensities in every day clinical practice, ie, a high number of repetitions, long therapy durations, frequent training sessions, and high patient activity during each of the repetitions is very challenging for numerous reasons [21]. One of the main advantages of advanced rehabilitation technology is that these devices can help therapists to intensify training on different levels. Movement therapy and specifically gait therapy can be very laborious for the therapists, requiring them to stop to rest before the patient reaches his or her full capacity. Robotic gait trainers can free the therapists from the manual labor, and hence, through reduced needs for physical effort, increase the amount of practiced repetitions [22]. For example, Lang et al [23] observed 230 sessions of traditional lower extremity therapy in individuals with stroke. The average number of steps taken was 357 (between 200 and 300 m) per training session. Zbogar et al [24] conducted a similar analysis but observed 561 physical therapy sessions with individuals with SCI. They counted an average of 51 steps, and these steps occurred primarily in patients who were already able to walk. With the help of an electromechanical gait trainer, the GT-1 (Reha-Stim, Berlin, Germany), patients with chronic hemiparesis, who were nonambulatory, conducted 800-1000 steps per 20-minute training session [25]. An individual with SCI, initially unable to walk 10 m between parallel bars even with the assistance of 2 persons, walked between 606 and 2424 m per 30-minute training session with the assistance of the Lokomat (Hocoma, Volketswil, Switzerland) [26]. Advanced gait trainers hence allowed a 2- to almost 10-fold increase in the number of conducted steps or gait distance during a training session.

Robotic gait trainers not only help to increase the number of steps practiced per training session, they also can help increase training duration or percentage of session actually spent with therapeutic activities by reducing the time needed for the therapists to rest. Also, by adding training with advanced technology in addition to regular therapy time, the number of sessions can be increased. For example, supervision can be reduced [27], and 1 therapist can provide therapy to more than 1 patient at the same time. In this group-like setting, resources can be freed to provide more training sessions.

However, only increasing the number of steps conducted or the duration or frequency of training is not sufficient. Another critical issue is the physical effort