WS3. Rehabilitation Robotics for Pediatric Applications + VISIT

Clinical Application of Robotics in Children with Cerebral Palsy

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Abstract. The intensity and the specificity of the training have been proven to be key factors in enhancing neuroplasticity and motor recovery in central nervous system disorders. Motivation, active participation and self-initiation of movements have also shown to be crucial for the success of therapy. Training with robotic devices may help increase these factors, and help understand the benefits this kind of therapy may have on treatment of children with CP.

1 Introduction

The term of cerebral palsy (CP) defines a group of disorders of movement and/or posture that are attributed to permanent damage to the developing brain [1]. CP is the most common cause of severe disability in childhood, with a prevalence of 3-4 per 1000 children at school age [2]. Most of the children with CP need to follow a rehabilitation program on a regular basis until they reach the adult age to maintain and gain function and to prevent complications [3].

There is evidence supporting that intensive task-oriented therapies facilitate motor recovery by enhancing the capacity of the central nervous system (CNS) to reorganize in response to different stimuli (neuroplasticity). Robotic devices are rehabilitation tools that provide highly specific, highly intensive therapy that allow for a higher number of repetitions of a trained task throughout the session [4]. These devices allow to perform the training in a controlled environment and in reproducible conditions. Robotic-assisted therapies also provide quantitative objective measures to monitor patient progress through the treatment [5]. There is growing interest in the use of robotics as rehabilitation tools for children with CP. The purpose of this abstract is to introduce basic concepts of the clinical use of robotic devices in rehabilitation. We will review the application of robots in the treatment of children with CP.

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2 Robot: Definition and Control Strategies

A robot is defined as a machine that can carry out a complex series of actions automatically, principally one activity programed by a computer. The basic characteristics of a robot are that includes sensors (pressure, motion or electromyographic among others), actuators to generate movement (commonly pneumatic, hydraulic or electromagnetic), power supplies (usually battery or electricity), control systems and software that are programed to complete the task. Another characteristic that is desirable for robotic in rehabilitation is *modularity*, that allows the robot to be dismounted into different modules, allowing for more customized and flexible trainings.

In the field of neurological diseases and disability, robotic devices can be conceived with two different motor goals [6]:

- For functional compensation/substitution, as an assistive device that usually replaces a function completely to passively increase mobility and independency.
- For motor rehabilitation, as a therapeutical tool that assists therapists, that helps facilitate motor and function recovery. This is our focus of interest in this manuscript.

The control system of the robot modulates how the machine reacts to the mechanical perturbation derived from the interaction with the user. This system also controls the production of a safe and proportional response, adequate to different patients and situations. According to control strategies, Marchal-Crespo found that most of the rehabilitation robotic devices in current use are distributed in these four categories or paradigms [7]:

- Assistance strategies: the most frequently used, especially within the concept of "assistance-as-needed". It can be provided through different techniques: control of impedance, weight-counterbalance, electromyography or motor-adaptation parameters.
- Challenged-based or disturbances strategies: resistance (usually "resistance-as-needed"), constraint-induced movement strategies and error amplification strategies.
- Haptic simulation: where the robot assists to practice routine movements in a virtual reality (VR) system.
- Coaching strategies: when the device does not interact physically with the patient.

3 Robotics in Cerebral Palsy

An increasing effort has been made to research the applicability of robotics to rehabilitate neurological conditions during the last decade. However, there is still a need to further investigate its potential role specifically in CP.

3.1 Robotic Devices for Lower Extremities

When focusing on robotic devices for lower extremities (LE) in CP, most research studies focus on gait training to treat gait disorders. The two main paradigms explored in this field are the use of an exoskeleton that drives the LE through the step cycle (treadmill training or overground walking), and the other follows the end-effector principle, where the feet are fixed on a plate that move the LE in a sequence similar to the gait cycle.

Robotic gait orthoses are useful tools to provide highly intensive stepping-specific training and are believed to impact on neuroplastic phenomena. The use of robot increases intensity, frequency, symmetry and specificity of gait rehabilitation while maintaining a physiological gait pattern, due to lower personal effort and costs. Robot-aided gait training also increases speed and walking distance during therapy sessions [8]. Although the concept is still innovative, the use of robots in pediatric population with CP has increased over the last years, and some models like Lokomat® System (Hocoma AG, Switzerland) are currently in use as a rehabilitation tool on a regular basis in a growing number of rehabilitation centers [9]. Robotic-assisted gait training improves speed, endurance, hip kinematics, step length and walking motor function in children with CP [10]. It also improves balance and has positive impact on the standing posture [11][12]. Another recent study has also proved that Lokomat® reduces muscle stiffness in children with CP [13]. Robotic therapy does not have adverse effects and is a well-tolerated procedure in children. There are also other robotic devices to train gait that use exoskeleton orthoses, like LOPES, ALEX, AutoAmbulator and others. Other machines like the Gait Trainer GT I, LokoHelp and HapticWalker explore the end-effector paradigm. However, most of the studies conducted with these devices have been done in other CNS pathologies such as stroke and spinal cord injury, and it is frequently postulated that the benefits found could also be extended to CP. Finally, new paradigms are currently being investigated, like a robotic system that help train stair climbing (G-EO System); the WalkTrainer, that combines hybrid orthoses and electrical stimulation, and the robotic device module called Anklebot, for ankle function recovery in CP [14] [15].

3.2 Robotic Devices for Upper Extremities

Scarce studies have been published to provide evidence for the efficacy of robotic systems for upper extremities (UE) in CP. Most of the UE robotic devices currently available focus on reaching and grasping tasks, usually using arm-weight counterbalancing strategies. Initial pilot studies show a positive impact of movement therapy with the commercially available robotic device InMotion2 robot (Interactive Motion Technologies, Cambridge, MA) to improve motor function and spasticity in CP. [16]. Other commercially available devices are the Armeo®Spring Pediatric (Hocoma AG, Switzerland) and Haptic Master® (Moog, The Netherlands). There is also a novel exoskeleton called Wilmington Robotic Exoskeleton (WREX) that assists people with neuromuscular diseases to use upper extremities, and thought to be potentially beneficial for children with CP.

4 Discussion

Therapies with robotic devices are well tolerated and provide new therapeutic possibilities for children with CP that need to be further explored. Among the advantages of robotic devices is that they offer the possibility to integrate VR environments. VR help children to engage and enjoy the therapy sessions while providing feedback. This is a way to increase motivation and active participation, and both features have been proved to be crucial for successful outcomes after therapy [17]. Some aspects regarding the most appropriate number and duration of sessions, frequency and personalizing strategies according to different pathologies or subtypes of CP should be investigated. It also remains a challenge to acquire a better understanding of the real impact of this technology on activities of daily living on CP. Moreover, no study has been done on the utility of robotic therapy as a complementary rehabilitation tool after traditional treatment of children with CP such tone management medication or neuro-orthopedic surgeries.

5 Conclusion

Current studies suggest that therapies with robotic devices may provide benefit for children with CP. However, further clinical controlled studies need to be completed to provide robust evidence about its utility in rehabilitation in CP.

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