Robot-assisted gait training for children with central motor disorders

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Introduction
During the last few years it has been successfully shown in the field of neuroscience that intensive, task-specific training can have a positive impact on the rehabilitation process for patients with central motor disorders relearning how to walk (Dobkin, Johannson). This training enables repair and reorganization processes to be introduced in the central nervous system (CNS), using neuronal plasticity. Factors such as the intensity of the training, its frequency, specificity, level of repetition with variations and motivation play an important role here in terms of motor learning (Winstein).

In order to increase the intensity and improve the quality of gait training, Body Weight Supported Treadmill Training (BWSTT) has also been introduced for children, in addition to the Conventional Over Ground Training (COGT) method (Schindl, Song). Both of these forms of therapy however have certain limitations. In order to establish a physiological and symmetrical gait pattern, up to three therapists are required to guide the patient's legs and facilitate the pelvis. It is also difficult to train at higher speeds, especially in the case of patients who are severely restricted in their ability to walk. For these reasons, automated and robot-assisted gait trainers have been developed (Hesse, Colombo).

Even in the case of children with cerebral palsy, the view has become established that activity and training - for spastic muscles too - can have a positive impact on their function (Damiano, Sterr, Dodd). The neurophysiological concept behind this is to modulate the neuronal networks or the whole cerebrospinal-neuromuscular axis through repetition of a preferably physiological gait pattern (Edgerton, Dietz).

Pediatric Lokomat® - a robotic gait orthosis
A clinical evaluation of the prototypes of the Pediatric Lokomat® - referred to from now on as the DGO (driven gait orthosis) - was carried out at the rehabilitation centre for children and young people (Affoltern am Albis, Switzerland) and in the Dr. von Haunerschen Kinderspital (Munich), in close cooperation with the manufacturer Hocoma (a spin-off company originating from the research laboratory at the Uniklinik Balgrist paraplegic centre in Zurich and the Swiss Federal Institute of Technology in Zurich).

From a technical perspective, the DGO is an exoskeleton, i.e. two leg braces which allow the patient to achieve a physiological step movement using both legs via integrated computer-controlled miniature motors.

The hip and knee joints are constantly monitored by software. A walking speed of between 1 and 3.2 km/h can be selected and adjusted during the training session. Dorsiflexion of the ankle joint is achieved using an elastic foot lifter. The DGO is adapted to the individual patient's anatomy. A dynamic body weight support system can take the strain of the patient's body weight to such an extent that a controlled stance phase can be achieved.

Children can be trained from the age of 4 (femur length 21 cm) to use the Pediatric Lokomat. In the case of young people with a femur length of 35 cm or more, the therapists can convert the device to the adult module within a very short time. To ensure the patient's safety while training, a number of safety features have been implemented, which cause the device to stop immediately in the event of any anomalies. Patients in wheelchairs can access the treadmill via a ramp, allowing them to be comfortably adjusted into the DGO.

Initial results and feedback

The Pediatric Lokomat has been in clinical use since the end of 2005. Initial results from a prospective application study involving 26 patients, which examined children from the age of 4 years in an inpatient (Affoltern, Switzerland) and outpatient (Munich) setting, look very promising. The study examined not only children with cerebral palsy (GMFCS II-IV), but also children with conditions caused by traumatic brain injury, stroke, spinal lesions and Guillain-Barré Syndrome.

In order to qualify for DGO training, recovering the ability to walk had to be a realistic rehabilitation objective. The following exclusion criteria were applied: severe contractures of the lower limbs, previous history of pathological fractures or indications of pronounced osteoporosis, restrictions on full exercise caused by surgery, pronounced disproportional bone growth, open skin lesions on the legs, thromboembolisms, cardiovascular instability, acute neurological disorders, aggressive or self-harming behavior.

It became noticeably apparent in the course of the study that even children with severe neurocognitive functional disorders could successfully be trained using the DGO. As a result, functional impairments of this kind were only specified as a relative contraindication if children could reliably confirm when they were experiencing pain or feeling unwell. An average of 20 therapy units of DGO training were carried out with children being treated as inpatients, while 12 units were carried out with outpatient children (1 therapy unit = 45 minutes). Whereas the outpatient children carried out almost exclusively Lokomat training (3 training units/week), the children being treated as inpatients completed 3-5 units per week, with the program being supplemented multimodally with other therapies.

Providing the physiotherapy team with thorough training and integrating DGO training as part of the organization are absolute requirements in order to achieve optimum benefit from and acceptance of the new treatment device.

It also proved useful carrying out a training trial with doctor consultation to verify the indication, spasticity, passive ranges of motion, antispastic measures and how the possible orthoses would fit before actually launching the program.

As an outcome parameter of the prospective application study, the following assessments were carried out in a pre-/post-design phase: Gross Motor Function Measurement (GMFM) dimensions for standing and walking, walking speed based on the 10-metre walk test (10MWT), 6-minute walk test (6MWT) und functional ambulation categories (FAC). The results indicated a significant improvement in walking speed and in the GMFM score in both groups. There was also a significant improvement indicated in the 6MWT and FAC in the inpatient group. Noticeably, the improvements in the GMFM were highlighted in the walking dimension in particular. This emphasizes the task-specific nature of DGO training. The DGO was successfully integrated as part of the clinical rehabilitation program. The level of motivation for carrying out DGO training was excellent among the large majority of children, while there was also a very high level of approval from the therapy team and parents.

Benefits and issues with robot-assisted gait training among children

Apart from offering longer distances to walk and more frequent training sessions, DGO training can also include higher and different speeds, which has not been possible to this extent up until now using COGT or BWSTT, partly as a result of staff resources (Winchester).

In order to improve the children's involvement in the movement process, the DGO offers a biofeedback system with three different graphical representations (Riener). This can be used by therapists for specific objectives, especially for training selective muscle groups. As the patient's legs are correctly guided by the DGO, the therapeutic focus can be placed instead on adjusting a physiological gait pattern and stance - a further benefit compared with COGT. Increasing the children's involvement in the training can be achieved by changing the gait speed or reducing the body weight support or guidance force. The intensity of the training can be continually adapted during the rehabilitation session.

Given that the training parameters of the DGO Lokomat® can be monitored and standardized, this offers the opportunity to obtain a better comparison between different centers in terms of gait training. Installed assessment instruments measure stiffness, power and passive ranges of motion from the hip and knee joint. These instruments still have to be validated for the children's module.

Numerous issues, such as dose- and age-related effectiveness of gait training, optimum support for motor learning among children using biofeedback, and validation of the assessment instruments are now being examined as part of interdisciplinary projects and in some cases, international cooperation projects. One interesting issue in particular is whether using intensive robot-assisted treadmill training with children from an early age could result in a better use of the potential of learning to walk at all. Furthermore, DGO treadmill training should help patients to achieve the best quality from their motor skills and not lose them over time, as is the case with many suspected congenital central motor disorders. In the case of patients who have acquired motor disorders, using the DGO could result in a reduction of the rehabilitation process. There is also the issue about the extent to which combining DGO training with other therapeutic and antispastic measures (e.g. botulinum toxin or biomechanical alterations performed by neuro-orthopedists) will result in a long-term, qualitative improvement in the patient's walking ability. A larger amount of patient data is required to be able to answer these questions. Consequently, a database called PeLoNet (Pediatric Lokomat Network) is being set up at the moment, which relevant centers can access.

Abstract
The process of spinal and cortical reorganization supported by task-specific training is dependent on dosage (Duncan). The Pediatric Lokomat® appears to be a very promising treatment device enabling children to learn/relearn how to walk, as it can provide almost perfect training conditions. The training can be adapted to achieve the optimum level in terms of frequency, intensity, as well as speed and speed variation. This is achieved while maintaining symmetry in the stance and swing phase. The main benefit of DGO training is probably derived from the amount of effort it saves, compared to conventional gait therapy or manual treadmill training, which may well produce the same effect, but involves more therapeutic staff and effort. In our opinion, it was as a result of this that the DGO was also used as a "high-frequency therapy" to be provided in blocks. Further studies with appropriate study designs are required to corroborate these hypotheses. DGO training should be used to improve the patient's ability to walk with a specific indication, and as part of a holistic approach, without competing with other therapeutic measures, in order to increase the participation of children based on the ICF model.

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Abbreviations

BWSTT	Body weight supported treadmill training
COGT	Conventional over ground training
CP	Cerebral palsy
DGO	Driven Gait Orthosis
GMFM	Gross Motor Function Measure
GMFCS	Gross Motor Function Classification System

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