Effects of robot-assisted gait training in stroke patients

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ABSTRACT

Stroke patients present significant gait deficits due to the complexity of their disabilities. Robot-assisted gait training (RGT), in addition to reducing the therapist's physical overload, ensures a simpler and safer environment for gait training, in which symmetrical and constant movement patterns of the lower limbs can be developed at higher speeds, and allows for a longer therapy session. Despite an increasing use of this equipment in rehabilitation, there is a lack of knowledge about the effects that can be promoted in paretic gait, as well as the training protocols applied to achieve them. **Objective:** Thus, this study aimed to assess the current evidence for efficacy of RGT in post-stroke individuals, with emphasis on gait performance. **Method:** For this, a survey of studies published in the last 10 years (2003-2013) with the terms "stroke" and "gait" and "robotics" was conducted in the PubMed, MedLine and LILACS databases. **Results:** Five studies were selected that met the inclusion criteria, including using the Lokomat robotic device (Hocoma, Volketswil) for gait training in post-stroke patients. The results obtained for each study considered the gains in linear gait parameters (speed and distance traveled) promoted by robotic therapy compared to conventional therapy. **Conclusion:** The data suggest that the use of robotic therapy in gait rehabilitation of post-stroke patients does not produce any more gains than those obtained with conventional therapy.

Keywords: Stroke, Gait, Robotics, Rehabilitation

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INTRODUCTION

With an incidence rate of 100 to 200 cases per 100,000 individuals in the western world,[1] strokes compromise the motor function significantly, with gait alteration being a predictor of disabilities in the performance of daily life functional activities.[2]

Despite the relevance of gait rehabilitation in achieving more independence in daily life activities,[2] gait training itself is frequently impossible for patients severely affected by stroke, due to the complexity of their disabilities, which demonstrates the need for a simpler and safer environment for this type of training.[3]

Gait training on a treadmill (TT) with partial body weight support (PBS) and manual assistance has been the focus of study in recent decades because it is seen as a technique that facilitates trunk and leg control, favoring gait training in post-stroke patients.[4,5]

However, a limitation in this type of training is the demand imposed on the physiotherapist to control and direct his patient's movements of the lower limbs. The manual assistance offered varies from therapist to therapist, making it a non-quantifiable variable, as well as the patient's required motor control and adjustments.[5,6]

To solve the limitations of the TT and PBS, automated movement systems have been developed to facilitate and optimize the gait training, replacing manual assistance with robotic devices.[4,5] In addition to diminishing the physical load imposed on the therapist, the robot-assisted gait training (RGT) provides a simpler and safer environment for gait training, in which symmetrical and constant patterns of lower limb movements can be developed at higher speeds, as well as allowing for longer therapy sessions.[2,3,4]

The first robotic device for gait training was developed in Switzerland and has been commercialized for many years under the name of Lokomat® (Hocoma, Volketswil).[3,5]

The Lokomat® was developed to automatize the training and thus reduce the physiotherapist's effort. It consists of a treadmill, a robot-driven gait orthosis, a suspension system that provides body weight support, and a computer for the individual gait adaptation within predefined safety limits.[7] This device, being adjustable in motor force, PBS, and speed, permits even the most incapacitated patients to be trained in accordance with their limitations.[5]

The Lokomat® combines new technologies with the recognized advantages of TT, such as ideal load,[8] suitable sensory stimuli,[9] ideal hip extension,[10] coordination between the lower limbs,[11] locomotion movements during specific tasks,[12] early beginning, and longer training sessions.[13] The training progresses from simple to complex, from easy to difficult, following motor learning principles and offering the basic aspects established for locomotion training such as the specificity of the task, the number of repetitions, and the intensity of the training.[5]

Despite the growing use of this equipment in gait rehabilitation for post-stroke individuals, little is known on the effects promoted on the gait of the patients and on the viability of using this equipment in the rehabilitation process.

OBJECTIVE

This study evaluates the current evidence on the efficacy of robotic gait with PBS for post-stroke individuals, with emphasis on gait performance, searching for correlations of the possible benefits of this type of training with the viability of acquisition and use of the robotic device.

METHOD

A literature survey was made on the PubMed, LILACS, and MedLine databases, referring to the publications of randomized controlled trials (RCT) over the last ten years (2003-2013), using the relationship between the keywords "stroke" AND "gait" AND "robotics".

The RCTs published in English were included, with participants of any gender and age with stroke; with right or left hemiparesis, regardless of the duration of the disease (acute or chronic), or level of gait ability, in which the locomotion training with the Lokomat® robotic orthosis was used and/or compared with another therapy employed to improve the gait function after a stroke.

Studies that were not RCTs were excluded, as well as bibliographic reviews, case studies, and studies that, although using the Lokomat® for robotic gait training, did so with patients suffering from pathologies other than stroke or whose analyzed variable was something other than their gait performance.

The variables analyzed were related to the linear parameters of the gait, with the objective of assessing alterations in the gait performance of patients pre- and post-gait training, as well as the differences found between robot-assisted training and other therapies.

Thus, tests that evaluated the gait speed and distance traveled were considered as primary variables for having been described in all the studies evaluated, whereas cadence, length of step, and duration of support phase were considered as secondary variables, for not having been mentioned in all the studies. The articles selected were evaluated and classified according to the Jadad scale.[14]

The five-item scale developed by Jadad[14] is the only known scale created with standard scale development techniques. Although the scale has been developed and validated to evaluate the quality of pain relief reports, it has been widely used in other clinical areas due to its efficiency.

The scale presents items whose questions elicit "yes" or "no" answers. The points attributed to items 1 and 2 depend on the quality of description of the methods used to generate the sequence of randomization and/or on the quality of description of the double-blind method. If the study is described as randomized and/or double-blind, but does not describe the methods used to generate the randomization sequence or the blinding conditions, one point is given in each case. If the method used to generate the randomization sequence and/or double-blind conditions is described, one additional point is given to each item, if the method is adequate. A method to generate randomization sequences was considered as adequate when it allowed each participant in the study to have the same chance of receiving each intervention, and if the investigators could not predict which would be the next intervention. The double-blinding was considered adequate if it was declared or implicit that neither the person who evaluated nor the study's participant was able to identify the intervention being evaluated. However, if the method to generate the randomization sequence and/or blinding was described, but not adequate, a score of zero is given for the item. The third item, losses and withdrawals, receives zero points for a negative answer and one point for a positive answer. For a positive answer, the number of losses and withdrawals and the reasons for them must be indicated in each one of the comparison groups. In case there are no losses, this must be indicated in the report.[14]

The Jadad scale[14] classification of the studies selected for this work was used to show the quality level of the works done on the theme evaluated and it was not part of the inclusion/exclusion criteria for this study.

RESULTS

Chart 1 shows a summary of the number of articles found on the selected databases.

The search on the "PubMed" database with the descriptors "stroke" AND "gait" AND "robotics" resulted in 49 articles. Among those, nine were systematic reviews, 30 used gait training robotic devices of different brands to analyze gait gains or other variables, and only 10 used the Lokomat®.

Among the studies that used the Lokomat®, four evaluated variables related to gait performance, four evaluated variables not related to gait performance (such as muscular activation, the influence of cognitive factors, and of virtual reality), and two were pilot studies that evaluated variables related to gait performance, with one composed of post-stroke individuals and the other composed of post-stroke and post-spinal cord injury individuals.

Thus, the studies that evaluated variables related to gait performance and the pilot study composed exclusively of post-stroke individuals were selected for this review (Chart 2).

The search in the "MedLine" database using the descriptors "stroke" AND "gait" AND "robotics" resulted in 47 articles. These 47 articles were already contained in the 49 articles previously found in the "PubMed" database and were therefore duplicate articles. For this reason, none of the 47 articles found in the "MedLine" database was selected, for those that fulfilled our inclusion criteria had already been included in our review. Finally, the search in the "LILACS" database using the descriptors "acidente vascular encefálico" AND "marcha" AND "robótica" did not present any result.

Following the determination to score each item evaluated, the final classification of each study selected for this review is shown below.

In their intervention protocols, the studies evaluated employed the robotic gait training through Lokomat® (RGT) either in comparison with conventional therapy (CT) or with conventional gait training (CGT) (Chart 3).

Husemann et al.[3] compared the effect on gait of the RGT to that of the CT in post-stroke patients in the acute phase of the lesion (28 days to six months). The number of patients that completed the study was 28. After being divided into the two groups, CT and RGT, the patients had 20 sessions. The TC patients received 30 minutes of conventional therapy daily, focusing on gait rehabilitation. Stability and trunk symmetry were worked, along with step initiation, and supporting weight on the paretic leg. In each session, the patient walked a few steps with the help of the therapists. The patients performed the treadmill training with the help of one or two therapists.

The RGT patients received daily 60-minute sessions, with 30 minutes of effective training. Initially, 30% of the body weight was supported, with the speed defined by the maximum tolerated by the patient and, according to what he tolerated, the weight support was reduced. The therapists encouraged the patients to perform the leg movements actively. After finishing 20 sessions, both groups received an additional 20 sessions of conventional therapy, totaling 40 sessions. Through the 10-meter walking test, no significant difference could be seen between the groups in relation to the gait speed developed by the patients. As for remaining supported on the paretic limb, the RGT group showed an increase in the support time, while the CT group showed no change. In regard to the speed, the RGT via Lokomat® was comparable to the result obtained in the CT.

Mayr et al.[5] employed a mixed protocol of CT and RGT to 16 post-stroke patients with one to ten months since stroke. The patients were randomized between two groups, each receiving five 45-minute sessions per week, for nine weeks, totaling 45 sessions. Each group was divided into three phases with three weeks for each phase. The experimental group division order was as follows: phase I (RGT); phase II (CT); phase III (RGT). However, in the control group division, each phase had the following representation: phase I (CT); phase II (RGT); phase III (CT). The RGT initially offered 40% of body weight support, which was gradually reduced to 0, duration time was progressively increased to a maximum of 30 minutes, the initial gait speed of 0.28 m/s was gradually increased to a maximum of 0.83 m/s, guiding force on the paretic leg was gradually reduced from 100% to 15%. The CT was based on neurophysiological concepts such as from Bobath, techniques by Perfetti, and gait training on the ground. In the experimental group, there was an increase in the distance traveled in the 6-minute walking test in phase III (RGT); the gait speed, measured by the 10-meter walking test, improved in the three phases, with more significant gains in phases I and III (RGT), with no significant gains during phase II (CT) in any variable analyzed. The control group presented an increase in the distance traveled in the 6-minute walking test in phases I (CT) and II (RGT) and an increase in gait speed in phase III (CT), however, there was no significant increase between the beginning and end of the treatment protocol.

Hornby et al.[6] compared the gains obtained through the CGT to those promoted by the RGT in post-stroke individuals with moderate to severe gait dysfunction. The 48 patients who comprised their sample each received 12 sessions of 30 minutes of either CGT or RGT. In both groups, between 30 and 40% of PBS was offered in the first session, with 10% decreases in the following sessions, as tolerated by the patient. The initial speed was 2 km/h with increases of 0.5 km/h each 10 minutes up to 3 km/h; visual feedback was made through a mirror and verbal commands to encourage the active movement of the paretic limb. The RGT group patients received assistance in the balance phase as well as in the support phase, while the CGT group received manual assistance from the therapist only when necessary. The gait parameters were evaluated with the Gait Mat II equipment and the 6-minute walking test. Increases were observed in the gait speed as well as in the support time on the paretic limb during the gait at the highest speed tolerated by the patient after the CGT, and these gains were more significant in individuals with a moderate degree of motor impairment than in those severely impaired.

Hidler et al.[4] compared the effects of CT to those of RGT in the acute post-stroke period (less than six months since stroke). The 63 patients who completed the study had 24 sessions, distributed into three weekly sessions of 90 minutes, with 45 minutes of intervention. The patients were divided into two groups: CT and RGT. The CT was structured according to the functional level of each individual and consisted of static and dynamic balance training, postural correction, gain in range of motion for upper and lower limbs, and gait training on the ground. The RGT was performed using the Lokomat®, with 40% PBS and a speed of 1.5 km/h (0.42 m/s) used in the first session; in the following sessions the PBS was adjusted so that the patient could walk at a speed of 1.5 km/h doing proper knee extension in the support phase. When the adequate level of PBS was defined, increases in the speed started to be made until

Chart 1. Bibliographic survey

	PubMed	MedLine	LILACS	Total
Results	49	47	0	96
Selected	5	0	0	5
Excluded	44	47	0	91

Chart 2. Classification of the articles selected according to the Jadad Scale

Study	Jadad
Husemann et al.[3]	5
Hidler et al.[4]	2
Mayr et al.[5]	4
Hornby et al.[6]	3
Lewek et al.[15]	3

Chart 3. Comparison of the results for each study

Study	Protocol	Result
Husemann et al.[3] Acute n: 28	CT x RGT 4 weeks + 4 weeks 5 sessions/week	No significant difference between the groups in relation to gait speed; increased duration on the paretic lower limb in the RGT group.
Hidler et al.[4] Acute n: 63	CT x RGT 24 sessions 3 sessions/week	More significant gains in gait speed and distance traveled in the CT group (CGT 64% RGT).
Mayr et al.[5] Acute and Chronic n: 16	Mixed CT and RGT 9 weeks 5 sessions/week	Both groups showed dramatic gains in gait speed and distance traveled in the RGT phase, with the most significant gains coming during this phase.
Hornby et al.[6] n: 48	CT x RGT 12 sessions	More significant gains in gait speed and duration on the paretic lower limb in the CGT group.
Lewek et al.[15] Chronic n: 19	CT x RGT 12 sessions 3 sessions/week	More significant gains in gait speed in the CGT group.

the patient reached the speed of 3 km/h and, then, the PBS was decreased from 5 to 10% in each session. The gait speed, assessed by the Gait Rite or Gait Mat II, showed an increase in both groups, with more significant gains in the conventional therapy group. The distance traveled in the 6-minute walking test showed the same result observed for speed. The gains obtained with CT were 64% greater than those obtained with the RGT.

Lewek et al.[15] also compared the CGT to the RGT in the post-stroke period; however, in their study the patients selected were those in the chronic phase of the lesion (after more than six months). The 19 patients who completed that study received 12 sessions, performed three times per week. In both groups the speed was gradually raised until it reached 3 km/h and the initial PBS of 40% was reduced as tolerated by the patient. Through the 10-minute walking test video recorded, the gait speed was calculated from the kinematic parameters obtained by the OrthoTrak, and showed a significant increase in the CGT group.

DISCUSSION

Few studies were found related to the results obtained in the robot-assisted gait training, which leads us to conclude that, despite the growing investment in developing new technologies that guarantees equipment with competitive prices and that remains accessible to different publics, little is known about the applicability of such resources.

Although the Lokomat® is the first robotic device for gait training, there is a lack of studies evaluating the effects of gait training through its use on the parameters evaluated in the present study. A search encompassing the last ten years resulted in only five articles that evaluated the effects of the Lokomat® on gait performance. Other articles used the Lokomat® for gait training, but the variables analyzed were not related to the gait parameters.

Through the Jadad scale[14] to classify the quality of the study, we found that although they were few, the studies found are articles

with relevant scores. With the maximum scale score being 5, with scores ≥ 3 considered "good" and ≤ 3 considered "bad", we obtained four scores above 3 and only one below.

Of the five studies selected for this work, two compared the RGT to the CT and three compared it to the CGT.

In relation to the primary variable chosen for analysis, gait speed, it was found that Husemann et al.[3] employed a more conventional design, distributing its patients between the CT and RGT groups, reaching the result where the RGT and CT gains were similar, while Mayr et al.[5] observed greater gains related to the RGT, using a different configuration, where both groups received CT as much as RGT, but with predominance of one of them in each group.

In this way, it can be stated that the result found by Husemann et al.[3] refers exclusively to the analysis of pure data, either from CT or RGT, while the result obtained by Mayr et al.[5] cannot totally isolate the action of each therapy proposed in relation to the result found in the gait speed of the patients.

Although the result from Husemann et al.,[3] where RGT and CT were found equally efficacious in promoting gait speed in acute post-stroke patients may be more reliable, Mayr et al.[5] makes an important observation that may become a way to orient the robotic therapy proposal. Through the protocol model used, they observed greater benefits in patients who start out with the Lokomat®, suggesting that the beginning of the motor re-learning process through RGT may assist the patient to achieve gross motor coordination more effectively, thereby developing a base for a more individualized and varied conventional therapy later.

The other three studies compared the RGT with the GT, with Hornby et al.[6] observing its effects in acute patients, while Hidler et al.[4] and Lewek et al.[15] worked with chronic patients. Based on three similar protocols, the three studies observed greater gains in relation to gait speed for patients who received assistance from a therapist during the therapy.

As a secondary variable, one the characteristics of hemiparetic gait was selected: the reduction of the unipodal support phase for the impaired lower limb.

Husemann et al.[3] observed that, when compared to CT, the RGT was superior in promoting a more symmetrical gait pattern when the duration on the paretic leg in acute patients was increased.

Locomotor training on the Lokomat® can optimize a few gains in relation to lack of balance, poor body alignment, joint instability, hypertonia, and alterations in the body perception, which are particularly difficult to work with conventional therapy in the initial phases of stroke recovery. The facilitation of work through the Lokomat® occurs through the PBS, the pelvis and trunk stabilization, the impedance to knee flexion, and, through the automated execution of a more physiological gait pattern, under space-time control.

However, the comparison between the RGT and CGT made by Hornby et al.[6] demonstrated that the time of weight sustainment on the paretic leg in chronic patients increased more significantly through manual assistance than through robotic assistance.

Offering symmetrical gait patterns through RGT did not promote gains in the unipodal support phase, while the changes observed in the CGT were substantial. This difference can be attributed to the greater variability and non-constriction of trajectories to increase error detection during the course of the therapist's assistance.

CONCLUSION

The present review demonstrates the need for studies that show greater precision in the results that can be achieved in patient rehabilitation through gait training with a robotic device.

Having data that justify the most suitable moment during rehabilitation at which to choose this type of training allows for a therapeutic direction, through which the time and the result of this process are optimized.

Thus, with this surveyed data, through which it is observed that positive results were achieved for transference of weight onto the paretic limb and body symmetry through gait training with the Lokomat®, it can be suggested that the most appropriate moment to choose this therapy would be at the initial phase of the therapeutic process, when the initial phase deficiencies of the patient can be worked safely so as to prepare him for conventional therapy and for conventional gait training, which has proved to be superior in gait rehabilitation.

Promoting improvement in body symmetry, balance, and motor control at the beginning of treatment-a moment that demands greater physical effort from the therapist due to the lesser participation of the patient, will diminish the therapist's physical overload and, at a later time in therapy, with the improvement of the patient's motor capacity, will allow the therapist to work in the more refined adjustments of global motor function and gait.

This new approach seeks to promote the optimization of the time the patient remains in the rehabilitation program and to maximally explore the time since stroke at which the possibilities of recovery are greater, in addition to reducing the overload on the therapist, making his work more efficacious.

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