

DEVELOPMENT OF A LOW COST ROBOTIC GAIT TRAINER

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INTRODUCTION

Stroke is one of the leading causes of disability in the United States with 750,000 individuals affected each year (1). A major residual effect of stroke is impaired walking ability. While 70-80% of adults who survive a stroke will regain the ability walk short distances, less than 50% are able to achieve even limited community ambulation (2). Each year the cost of stroke is nearly \$30 billion in direct medical costs and nearly \$20 billion in lost productivity (3). Residual disability from stroke has high social and economic impact. Restoration of gait is a major goal of rehabilitation for persons with stroke.

The current focus for gait restoration due to paralysis associated with stroke is on task specific, repetitive rehabilitation techniques. This means that in order to relearn a normal walking gait pattern the patient must practice walking. Body weight supported treadmill training is a task specific therapy that has been shown to improve gait in hemiparetic stroke subjects (4), however it has failed to become widely used because of the high staffing costs required to perform the treatment (5).

More recently, the field of robot-assisted motor rehabilitation has emerged and is rapidly developing. In this type of training, a machine guides the lower extremities in a normal gait pattern while the body weight of the subject is supported. In a recent review of robotic-assisted gait training devices used in post stroke rehabilitation, the authors found that robotic gait trainers were as effective as body weight supported treadmill training (6). One major disadvantage of these robotic gait trainers is the actual cost of the device. While the number of staff required to perform the therapy is reduced, these devices can be very expensive and often too expensive for widespread clinical application.

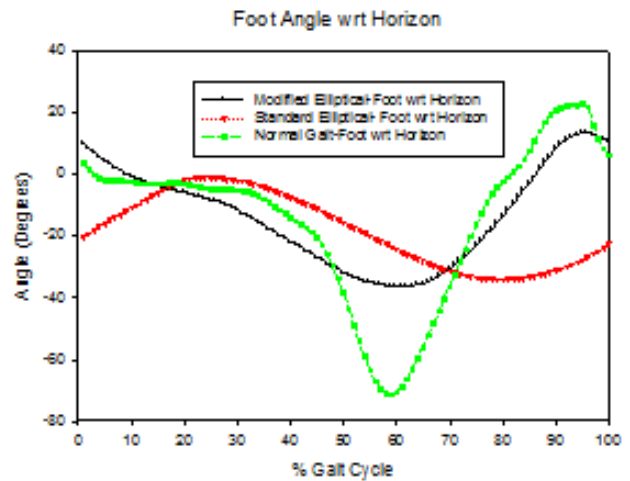


Figure 1: Foot angles with respect to horizon during ambulation on the modified and non-modified elliptical trainer and during normal gait.

Our solution to this problem was to create a low-cost robotic device that has the ability to simulate normal gait. The platform for our design is a commercially available elliptical trainer (\$600) which has been modified and coupled with a body-weight support system.

METHODS

The elliptical based robotic gait trainer (EBRGT) was developed from a commercially available elliptical trainer. Elliptical trainers provide a lower extremity motion that simulates walking or running. The foot is moved in an elliptical pattern on a leaf spring shaped ski. This provides some shock attenuation and ankle movement, however, the ankle joint stays in a neutral to plantar-flexed position throughout the gait cycle with this design. This is depicted by the red line in Figure 1. This pattern is different from normal gait, depicted by the green line in Figure 1.

To create the EBRGT, the footplates of the elliptical trainer were modified to allow sagittal plane ankle articulation in a controlled trajectory that mimics

normal gait. First a rigid platform was attached at one end to the ski. The other end was attached directly to the peg supporting the back end of the ski. This was done so that the impact absorbing quality of the leaf spring ski could still be exploited, but also provided a rigid surface to mount the mechanical components for the modification.

A new footplate was created and attached to the rigid platform via a single axis bearing, allowing sagittal plane articulation. Footplate motion was driven by an AC servo motor, coupled with a worm gear box and mechanically linked to the footplate via a belt drive. These modifications were made to both the left and right side of the elliptical trainer.

The motion of each footplate was controlled by a separate single axis controller. To link the motion of the left and right footplate, each controller received feedback from a common optical encoder mounted on the axis of the elliptical trainer flywheel. Figure 2 illustrates the control schematic. Recall that the flywheel drives the motion of both skis, with the left and right ski being 180 degrees out of phase. The motion of the footplate was controlled as follows: The user drives the motion of the elliptical by applying force to the footplates. This causes the flywheel to start turning. The encoder provides feedback about the position of the flywheel to the controllers and the position of the footplate (orientation in the sagittal plane) is adjusted based on the position of the flywheel. Specific events in a normal gait cycle have been synchronized to the position of the flywheel on the elliptical.

RESULTS AND DISCUSSION

The design of the EBRGT allows active control of the orientation of the footplate in the sagittal plane.

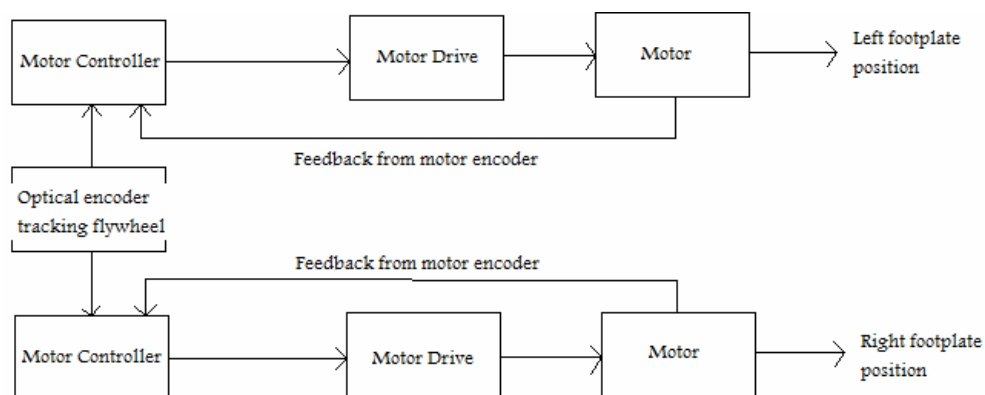


Figure 2: EBRGT control block diagram.

In a previous iteration of the design, we were able to achieve a sagittal plane articulation of the footplate similar to an average normal gait pattern using only a passive mechanical modification to the elliptical. Figure 2 illustrates the footplate pattern for an entire gait cycle for three different conditions: elliptical with passive mechanical modifications, elliptical before modifications, and level surface walking. Note that the modified elliptical pattern (black) more closely resembles normal gait (green), as compared to the non-modified elliptical pattern (red). The new active system allows for the footplate to follow a pattern that mimics normal gait, while still allowing the pattern to be adjusted for each user.

CONCLUSIONS

The EBRGT may be a low-cost solution for robotic gait training in a population suffering gait deficits secondary to stroke. Studies are in progress to test the effectiveness of the EBRGT as a gait rehabilitation tool for patients with gait deficits secondary to stroke.

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