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Initial Results of the Gait Enhancing Mobile Shoe on Individuals with Stroke

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***Abstract*— The Gait Enhancing Mobile Shoe (GEMS) can generate a motion to a foot that is capable of changing interlimb coordination while walking over ground. The generated motion is similar to that felt when walking on a split-belt treadmill, but while walking over ground where the sensory information of the real-world task will be experienced. Three subjects with a unilateral stroke walked on the GEMS for 12 sessions over 4 weeks with pre- and post-training tests. The results from this ongoing study show that the subjects' step length and double limb support symmetry improved following the training.**

I. INTRODUCTION

The Gait Enhancing Mobile Shoe (GEMS) is designed to change interlimb coordination and strengthening the paretic leg of individuals with asymmetric walking patterns caused by stroke. The concept of the GEMS is similar to that of a split-belt treadmill [1], but allows the individual to walk over ground, which is hypothesized to help with long-term retention of the altered gait pattern [2]. In addition, the GEMS can be manufactured for a lower price and can, thus, be made available in more locations and could enable a home-based gait rehabilitation solution.

The GEMS is completely passive and uses spiral-like (non-constant radius) wheels [3], which redirect the downward force generated during walking into a backward force that generates a consistent motion. By not utilizing actuators and fabricating the shoe using rapid manufactured glass-filled nylon, the GEMS weighs approximately 900 g. Small unidirectional dampers on the front and back axels prevent uncontrolled motions. After the shoe stops moving backward, the user toes off, and springs attached to the axels reset the position of the wheels for the next step. The front of the GEMS is able to pivot to more naturally conform to the user's toe-off. The motion of the shoe can be seen in Figure 1.

II. METHODS

The experiment is based on protocol NCT02185404 as listed on ClinicalTrials.gov . Before training, subjects' gait patterns are evaluated using a ProtoKinetics Zeno Walkway (ProtoKinetics, Havertown, PA). They then complete 4 weeks of training 3 times a week under the guidance of a physical therapist. Each of the 12 sessions includes 6 bouts of walking on the GEMS for approximately 5 minutes with breaks between bouts. Their gait is tested one week after training.

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*Reed and Handzic have a patent (US 9,295,302) related to this work that is licensed to Moterum, LLC. A management plan has been implemented and followed to reduce any effects of these conflicts of interest.

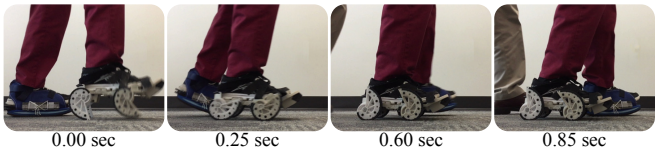

Fig. 1. As the wearer takes a step, the GEMS passively pushes the foot backward during stance. The backward motion of the GEMS is similar to the motion produced on a split-belt treadmill, but the GEMS allows walking over ground. In addition, the GEMS works to strengthen the paretic leg by slightly destabilizing the healthy leg, which encourages the wearer to use their paretic leg more. A flexible height and weight matched platform worn on the opposite foot equalizes the added height and weight of the GEMS.

All subjects agreed to participate in this study and signed a consent form that was approved by the Western Institutional Review Board. Three subjects (1 male and 2 females), aged 57-74 years old with right hemisphere stroke, completed the training thus far and the length of time since stroke ranged from 1.2 to 5.4 years.

III. RESULTS & DISCUSSION

Symmetry was calculated as $100 * \frac{\text{abs}(M_{\text{paretic}} - M_{\text{nonparetic}})}{0.5*(M_{\text{paretic}} + M_{\text{nonparetic}})}$ where M is one of the three measures shown in Table I, and a value of 0 indicates symmetry. Comparisons were made between gait evaluations conducted before training and after completion of training. A repeated-measures ANOVA was used to analyze all the steps in the pre- and post-tests.

The results, summarized in Table I, demonstrate an improvement on step length and double limb support, but stance phase symmetry was unchanged. These results are inline with the expected change in gait patterns based on split-belt treadmill studies using the same number of training sessions [4]. These results look promising, but are only based on three subjects. The study is ongoing, so additional subject data will be reported when completed.

TABLE I
COMPARISON OF SYMMETRIES BEFORE AND AFTER TRAINING

Measure	Pre-training	Post-training	Significance
Step Length Symmetry	22.9%	18.6%	**p<.01**
Double Limb Support Phase Symmetry	29.2%	23.8%	**p<.05**
Stance Phase Symmetry	19.9%	20.3%	p>.05

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