White Paper: Improving mobility for patients recovering from neurological injuries using Kickstart

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Overview

Walking rehabilitation strategies for stroke and other neurological conditions aim to restore lost function by promoting motor re-learning and neural plasticity. Motor learning is known to accelerate when practice methods are meaningful, repetitive, intensive and task-specific[1]. A growing body of evidence also suggests that active exercises with voluntary movements are important in enhancing neural plasticity[2]. However, without the strength, motor control and endurance to perform proper walking movements, patients can be limited in their ability to train and recovery can plateau.

This white paper presents the design and clinical results for three patients using Kickstart, a neurorehabilitation device designed to accelerate walking recovery by enabling users to walk and train at higher capacities than otherwise possible. Inspired by horse anatomy[3-5], Kickstart utilizes a patented Exotendon™ that functions like an artificial tendon to provide stability and amplify a patient's existing strength and motor control.

Three cases are presented of patients who had reached a plateau in their walking recovery prior to starting Kickstart use: one patient with an incomplete spinal cord injury (SCI) and two cases of stroke survivors, all of whom used Kickstart as part of their normal clinical care. Clinical outcomes were measured over a 10 month period and included the Six Minute Walk Test, Ten Meter Walk Test, and Timed Up and Go (TUG) Test. All three cases improved their walking speeds to higher levels of community ambulation wearing Kickstart and demonstrated therapeutic effects in the form of weaning off from the system. The results suggest that Kickstart can improve mobility for people with chronic impairments due to neurological injuries.

Kickstart Technology Background

Kickstart's Exotendon™ is a bio-inspired technology that amplifies a user's physical strength and stability to enable proper walking. Large terrestrial animals often make use of muscle-tendon units spanning multiple joints to generate force without metabolic cost by taking advantage of the passive elastic properties in the tendons[6, 7]. This is especially true of horses – equine hindlimbs have evolved to have short muscles coupled with long tendons spanning multiple joints[3-5]. By storing energy in these long tendon structures in early stance, horses are able to generate propulsive forces with 50% less metabolic energy than humans and rapidly protract the limb to allow for advancement of the limb through swing phase without dragging the hoof on the ground[8-10].

Research at the Cleveland Clinic by Dr. A. J. van den Bogert explored through computational modeling the utility of adding parallel elastic structures that stretch around pulleys external to the human body for reducing the muscular forces required for locomotion[11]. In this work, he created a computational inverse dynamic model and optimized pulley radii and elastic stiffness to minimize joint moments and forces. This optimization found that a system consisting of an elastic structure stretching around pulleys located at the joint centers of the hip, knee, and ankle could reduce joint moments and powers by about 50% for able-bodied gait.

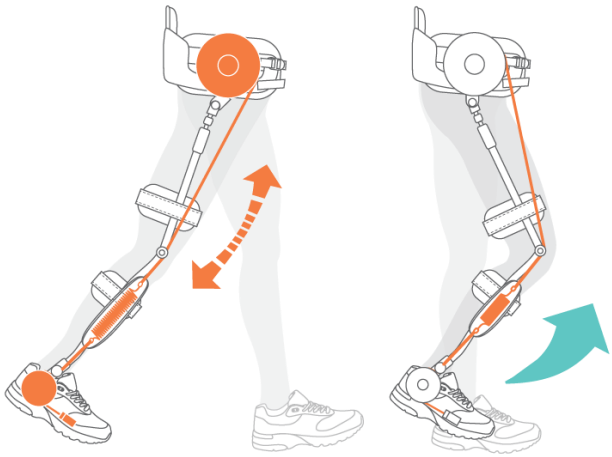

Figure 1: Using the Exotendon system, Kickstart provides users with swing assistance, added stability and feedback for proper gait mechanics.

Kickstart is a wearable rehabilitation system that utilizes a patented Exotendon™ based on van den Bogert's model[11] (Fig 1). As a user begins to take a step, the Exotendon attached to the system's support structure stretches to store energy, providing support and stability. At the end of the step, this stored energy is returned to facilitate hip flexion and ankle plantarflexion – parameters associated with significant improvements in walking speed and gait mechanics in individuals post-stroke[12].

Case 1: Incomplete Spinal Cord Injury

Participant 1 had an incomplete T-10 spinal cord injury seven years prior to starting his Kickstart use. He lived at home and was independent in self-care. He stood in a stander daily, transferred independently, and could walk very short distances of a few steps with a walker with close guarding. He was able to walk independently in a pool with flotation devices. Participant 1 presented with weakness in both lower extremities impacting all muscle groups. He had poor minus strength on the left and fair strength on the right for hip flexors, knee extensors, ankle plantarflexors and ankle dorsiflexors. Sensation was poor, particularly on the left side on which he could not discriminate the position of his hip, knee or ankle. Prior to working with Kickstart, his therapy was focused on body-weight supported treadmill training once a week and aquatic therapy four days a week. In this case study, the subject used the Kickstart Walking System for supervised overground walking once a week for eight months. The Six Minute Walk Test and Ten Meter Walk Test were recorded.

Case 1 Outcomes

With the Kickstart Walking System, the subject was able to make substantial gains in both walking speed and endurance (Fig 2). His walking speed improved at its maximum to 0.40 m/s, a substantial increase from the 0.19 m/s he was able to achieve without Kickstart and above threshold considered for limited community ambulation[13, 14]. Endurance improved even more dramatically, with six minute walk distances improving from 25 meters to 125 meters, a five-fold increase. During some therapy sessions, the subject was able walk outside for 30-45 minutes and covered the distance of a city block. He also demonstrated improved sensation and proprioception by self-report. Lastly, his right leg improved enough to permit the removal of the right side of Kickstart, so he now uses a unilateral configuration on the left side only.

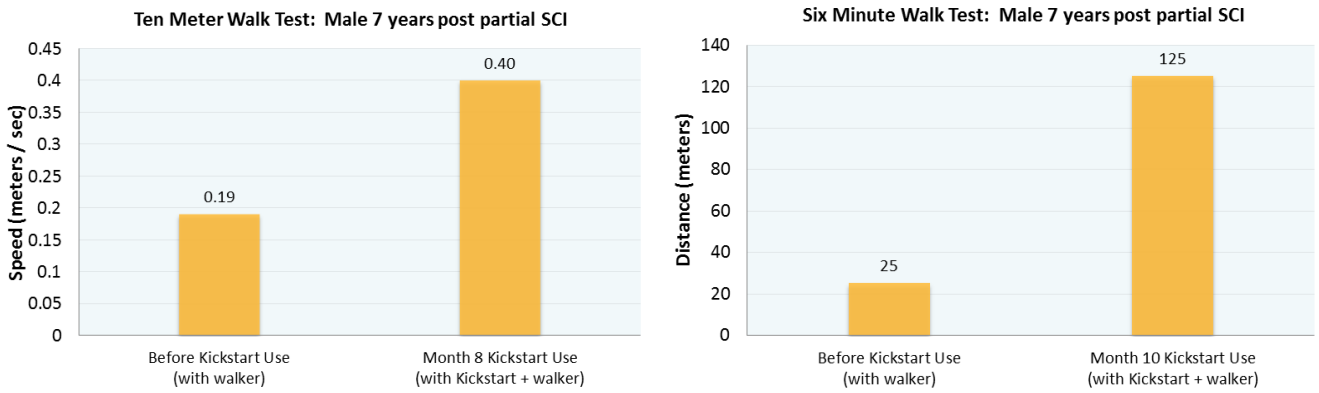

Figure 2: Ten Meter Walk Test and Six Minute Walk Test data for Case 1 patient (Incomplete spinal cord injury).

Case 2: Cerebrovascular Accident

Participant 2 had a cerebrovascular accident 10 years prior to starting his Kickstart use. He lived independently at home and walked independently with a cane and a carbon-fiber ankle foot orthosis on the right leg. He could not walk reciprocally up and down the stairs. In the lower right limb he had poor minus strength in his hip flexors, ankle dorsiflexors, and ankle plantarflexors with fair minus strength at the knee. He walked with a stiff knee gait and external rotation of the hip which limited his walking speed and efficiency. At home he walked without a cane, but in the community he used a cane. With a unilateral Kickstart Walking System, he performed a series of supervised functional exercises which included squats, knee raises, walking over obstacles, and stair ascents and descents (2x/month for 2 months). He also used Kickstart daily for walking at home and in the community.

Case 2 Outcomes

Participant 2 also demonstrated significant improvements in all metrics (Fig 3). His walking speed improved from 0.45 m/s to 0.92 m/s, which is fast enough to be classified as an independent community ambulator[14], as this speed is fast enough to cross the street before a stop light changes. His endurance also improved dramatically (123 m in the six minute walk to 224 m). TUG times improved as well, reducing to 14.6 s from a pre-Kickstart maximum of 24 s. This is clinically significant as his TUG times with Kickstart are within the range considered minimally at risk for falling[15]. Additionally, a qualitative assessment of his gait revealed that he is less externally rotated and walks with increased knee flexion using Kickstart rather than a stiff-legged gait. The subject also demonstrated improved awareness of the limb in space by self-report and was able to walk reciprocally up and down the stairs in his home with Kickstart. After prolonged use, the subject has demonstrated enough improvement to maintain his mobility and independence without Kickstart.

Figure 3: Ten Meter Walk Test, Six Minute Walk Test and Timed Up and Go Test data for Case 2 patient (CVA).

Case 3: Cerebrovascular Accident

Participant 3 had a cerebrovascular accident 20 years prior to starting Kickstart use. She lived independently at home, walked independently with a cane for short distances up to one city block and utilized a Segway for long distance mobility. She could not walk reciprocally up and down the stairs. This participant presented with left hemiparesis of the arm and leg, with fair strength in her hip flexors, knee extensors, and knee flexors and poor strength in the ankle dorsiflexors. She walked with circumduction at the hip which limited her walking speed and efficiency. In this case study, the participant used a unilateral Kickstart daily at home and in the community but did not attend physical therapy.

Case 3 Outcomes

Case 3 also demonstrated significant improvements in all metrics (Fig 4). Her walking speed improved from 0.42 m/s to 0.94 m/s which is fast enough to be classified as an independent community ambulator[14], as this speed is fast enough to cross the street before a stop light changes. Her endurance also improved dramatically (120 m in the six minute walk to 226 m). Additionally, the participant was able to walk reciprocally up and down the stairs in her home with Kickstart. After prolonged use, the subject has demonstrated enough improvement that she can now walk independently without Kickstart during daily living activities.

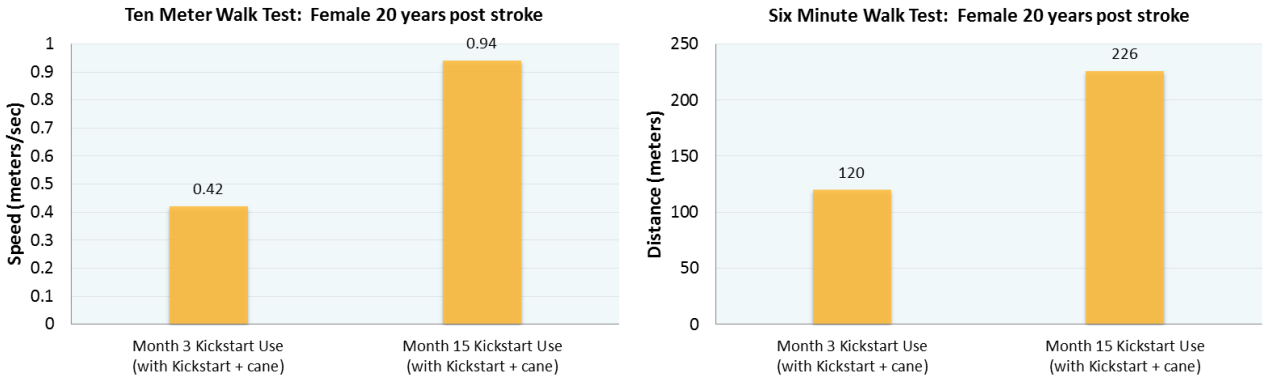

Figure 4: Ten Meter Walk Test and Six Minute Walk Test data for Case 3 patient (CVA).

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