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Development of a Cable Driven Flexible Robotic Rehabilitation Glove

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Introduction: Annually, some 600,000 people are left with loss of motor function as a result of stroke [1]. The ensuing weakness, hemiparesis, typically afflicts the limbs on one side of the body. Recovery of motor function can be regained through repetitive motion exercises. It has been shown that robotic assistance in rehabilitation can improve outcomes [2]. Current devices consist primarily of large devices used with a therapist, or unpowered orthotics providing rigid support. This work focused on development of a soft, lightweight and low-cost robotic glove that patients can wear and use to recover hand functionality, utilizing a portable and intuitive interface.

Materials and Methods: A robotic glove system for hand rehabilitation was designed and prototyped (Fig. 1). The device is a fully flexible glove with pairs of cables for each finger attached to it that is made out of a spandex material, due to its flexible yet supportive form-fitting weave. The cables originate at each finger tip, are guided along each finger, run up the length of the arm and around the shoulder to a backpack, where they attach to servomotors through spools. Separate flexion and extension cabling is used to independently control each finger without any rigid exoskeleton. The cable guides are 3D printed plastic pieces that center the cables along each finger. Kevlar thread (cable) is fed through flexible tubing forming a Bowden cable system to allow the actuators to be located remotely from the glove. The Bowden cable system runs along the length of the arm to a backpack servomotor housing – by placing the actuators in a backpack, the unneeded weight is removed from the user's forearm and hand. The inner Kevlar thread is wound around custom-made spools. Each spool is mounted on a servomotor and actuates a pair of cables and was sized to take up the needed amount of line for both the flexion and extension cables from the individual digit it controls. The system controls each finger independently and moves each digit to any position between open and closed grip. Custom electronics enable each motor to be operated in either position (angle) or force (current) control modes; in both cases current limits may be set on each servomotor individually for safety or as part of the rehabilitation treatment regimine. The maximum tensile force and grip force was 15 N. Electromyography (EMG) electrodes are incorporated into the sleeve over the forearm and are processed by the custom electronics in the glove control system.

Results and Discussion: The glove has three different primary operating modes: a switched mode, a programed routine, and utilizing integrated EMG sensing. In the switch control mode, the glove is controlled by a three-position switch that opens, closes and holds the hand's current position. The programmed mode allows a therapist to preprogram the glove to actuate a specific routine; this allows a therapist to create exercise regimens for their patient. It is anticipated that this will also be extended to take an input from a non-actuated position or force sensing "mimic glove" that can be worn by the therapist or on the unafected hand. The EMG mode allows the user to control the glove based on their myoelectric signals. Within this mode, the system has the ability to provide active resistance or active assistance: active resistance provides a resistive force against the opening or closing of the hand to build musculature, while active assistance aids the user in their intended movement by providing force in the same direction.

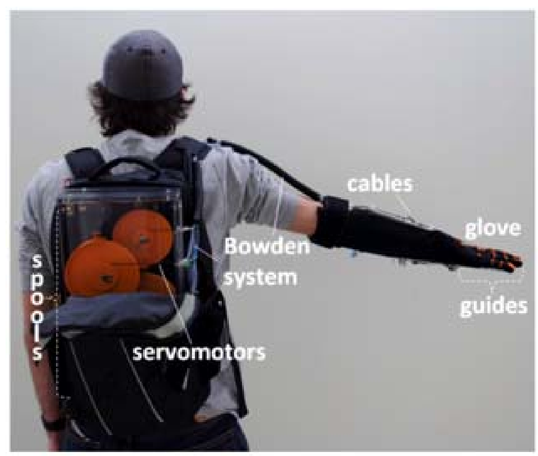

Figure 1. Prototype assembly: user wears the flexible glove with pairs of cables for each finger running through guide tubes, up the length of the arm, to five motorized spools in a lightweight backpack.

Conclusions: Overall the prototype met the objectives of the design. It provided a portable and effective means of repetitively opening and closing the user's hand, while allowing adjustability in terms of tension, hand size, control and implementation. The prototype rehabilitative robotic glove proved that the design is effective and with future developments, its potential implementation can be applied to other uses for assistance and rehabilitation.

References: [1] National Stroke Association. Muscle Weakness after Stroke: Hemiparesis. *North Star Neurosci*, 2006. [2] Abdullah, Tarry, Lambert, Barreca, Allen. Results of Clinicians Using a Therapeutic Robotic System in an Inpatient Stroke Rehabilitation Unit. *J NeuroEng* (BioMed Central) 8(50), 2011.