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A Pneumatic Muscle Hand Therapy Device

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Abstract— **Intensive repetitive therapy improves function and quality of life for stroke patients. Intense therapies to overcome upper extremity impairment are beneficial, however, they are expensive because, in part, they rely on individualized interaction between the patient and rehabilitation specialist. The development of a pneumatic muscle driven hand therapy device, the Mentor™, reinforces the need for volitional activation of joint movement while concurrently offering knowledge of results about range of motion, muscle activity or resistance to movement. The device is well tolerated and has received favorable comments from stroke survivors, their caregivers, and therapists.**

Keywords— **Pneumatic muscle, hand therapy, biofeedback**

I. Introduction

Recent research has shown that the brain has more capability to recover function after injury than once believed. Maps showing motor cortical representation shrink with inactivity following lesions and may expand with subsequent activity [1-5]. These findings form the basis for new therapeutic treatment of patients with stroke and traumatic brain injury. Traditional therapies for neurological rehabilitation are very labor intensive. Three to four percent of the national health budget involves personalized physical therapy [6]. The use of robotic devices to assist in these therapies is reviewed in [7]. There is a need for affordable, practical and multi-dimensional devices to assist therapy [6]. The device described in this paper is designed to provide active repetitive therapy to the fingers and wrist. Many important activities of daily living, such as grooming, dressing and eating depend on two-handed function [8] and improvement of hand function is important, because a usable hand provides incentive to a patient to work on rehabilitation of the elbow and shoulder.

II. DESIGN

The design goals were to develop a device for improvement of hand function in stroke survivors that incorporates recent findings from applied neuroscience studies. Thus the device was designed to reinforce the need for volitional activation of joint movement while concurrently offering knowledge of results about range of motion, muscle activity or resistance to movement. The device is able to provide the treatment modalities of repetitive practice, EMG biofeedback and force biofeedback in the clinic or home environment. The device is called the Mentor™, because it is designed to encourage patients to help themselves.

Traditional robots are stiff. The use of robotic actuation in exoskeleton applications presents a mismatch in compliance of the actuator and the limb being moved. Impedance control of actuators has had success in addressing this problem. Our approach was to utilize the compliant artificial air muscle as an actuator. The artificial muscle exhibits many of the properties of human muscle. It consists of an expandable internal bladder, e.g., a rubber tube, surrounded by a braided shell. When the internal bladder is pressurized, it expands radially against the braided shell. The pressure on the inside of the braid causes it to contract. Braided finger traps used to hold fingers on traction devices contract radially when pulled. The air muscle works in the same manner only in the opposite direction, i.e., increasing the diameter causes it to shorten. Like human muscle, the air muscle has spring-like characteristics, is flexible, and is lightweight. First used in the 1950's for powered braces [9], the force-deflection characteristics can be made similar to those of human muscle. Microprocessor controlled mini-compressors supply air pressure. Major advantages of the air muscle are its flexibility and ease of adaptation to address the specific loss of function exhibited by a patient. This configuration is often referred to as the McKibben Artificial Muscle and has three times the pull force of an air piston of the same cross sectional area.

The overall system design framework and microprocessor controller can adapt to new rehabilitation methods as they are developed and tested. An illustration of the device, its components and proper donning are illustrated in Figure 1. An air muscle is attached to the proximal forearm. Activation of the air muscle rotates a bar about a pivot point

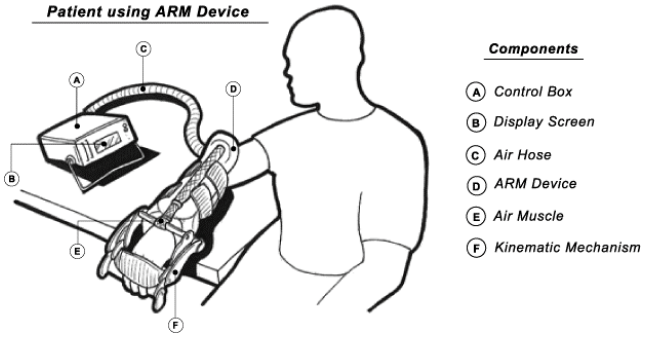

Figure 1

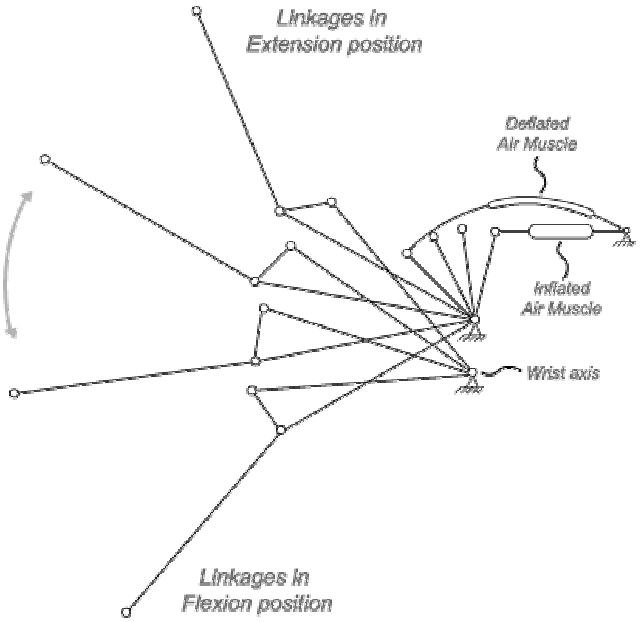

Figure 2

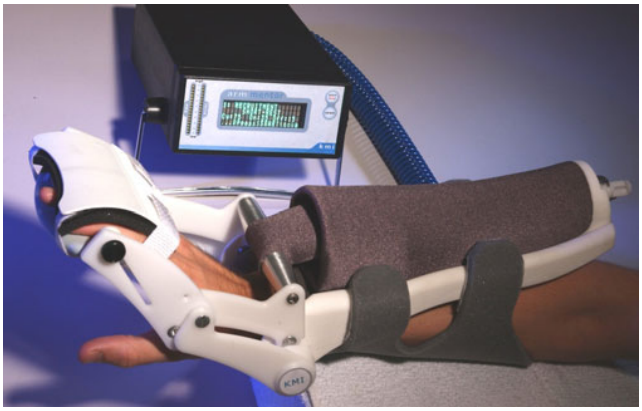

Figure 3

positioned inline with the flexion axis of the wrist. This action extends the wrist and fingers and operates a modified Watt mechanism that extends the fingers. Wrist extension position is measured by a potentiometer, which is centered inline with the pivot point and thus the wrist flexion axis. Resistance to wrist flexion is measured. The force output is a measure of the resistance offered by multi-joint stiffness attributable to changes in visco-elastic properties and muscle length stretch sensitivity in both the finger and wrist flexor muscle groups. Since spastic flexor muscles are usually velocity sensitive, the velocity of actuation was chosen to be 5 degrees per second with no loading. With the weight of a flaccid hand, this rate decreases to 3.8 degrees per second and with resistance the rate is 2.7 degrees per second. Through air muscle calibration, the extension of the air muscle as recorded by the potentiometer provides a measure of the resisting load. The mechanism that provides the coordinated motion of the fingers and wrist is shown in Figure 2. Four positions of the linkage are shown. Fully deflated and fully inflated positions of the air muscles at the extremes of motion are also shown. The furthest left hand set of points is the spiral trajectory of the distal finger tips. The latest version of the device is shown in Figure 3.

III. Results

Five therapists (2 occupational therapists and 3 physical therapists) who treat stroke patients, and five caregivers of stroke patients, were recruited to participate in a pilot evaluation of the Mentor™. Each participant was trained on the use of the device and briefed on the basis for the incorporated therapy protocols and had a device for a minimum of one week of home use. Questionnaires were separated into sections including: (1) Initial Impressions, (2) My Use, (3) Spouse (or partner) or Client Use, and (4) Future. Overall, both therapists and caregivers did not think the device was too complex or that clients/spouses would have difficulty understanding how to use the device. In addition, no one indicated that discomfort would be a problem. Caregivers noted that they could encourage their spouse to use the device, and that they would not have trouble assisting in using the device. There was agreement from spouses and therapists that individuals would need help using the device and that in fact they did have to help the individual. No individuals reported apprehension in using the device, nor did any experience pain. All participants reported that using the device over time would not be difficult. In addition, all reported that: the device helped them;, they were more hopeful of gaining additional function; and they would use the device in the future.

IV. Discussion and conclusions

Stroke is the leading cause of adult disability in the United. Many research studies, both animal and human, have shown that continued recovery of functional skills in stroke patients occurs with forced use therapy protocols. However, health insurers often limit or deny rehabilitation to stroke survivors claiming patients plateau several months post stroke [11]. Robotic devices that provide treatment capability in the home and clinic are a way to provide cost effective therapy to a wider population for a longer period of time. That is the purpose of the pneumatic muscle driven Mentor™ hand therapy device. The utility of the air muscle drive resides in its unique combination of attributes: low stiffness, low cost, lightweight, low profile, and low noise operation. The device has been shown to be well tolerated, has received favorable comments from caregivers and stroke survivors. This air muscle technology is being applied to the development of an upper extremity therapy robot with Arizona State University under NIH contract NO1-HD-3-3353.

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