NEW ASSISTIVE GLOVE FOR STROKE SURVIVORS USING ADVANCED DYNAMIC BIOMECHANICAL MODEL

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MOTIVATION

- Hemiparetic stroke survivors have difficulty in performing daily tasks such as picking up and releasing objects due to severely impaired finger extension [1,2].
- A cable-driven assistive glove intends to help extend stroke survivors' fingers [3]. However, the current glove applies suboptimal moments and compressive forces across the finger joints, causing unnatural finger opening trajectory and pain.

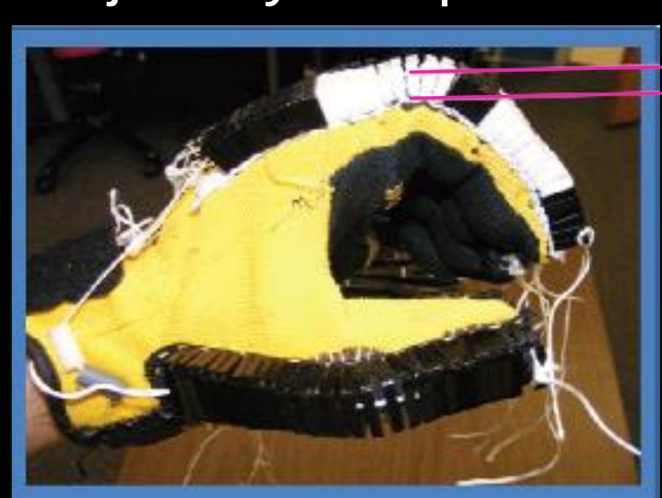

Fig 1. The current cable-driven assistive glove has the cable running parallel to the dorsal finger (i.e., constant cable support heights throughout the length of the finger) [3].

OBJECTIVE

- To improve the current cable-driven assistive glove design for natural hand opening trajectory and reduced compressive forces for stroke survivors by dynamic biomechanical modeling.

APPROACH

1. Develop a biomechanical hand model that predicts finger opening trajectory (joint angles over time) given cable support heights and tension.
2. Determine the normal hand opening trajectory.
3. Optimize cable support heights and cable tension to best fit the simulation results into normal hand opening trajectory.
4. Build prototypes of the optimal assistive glove.
5. Clinically evaluate the optimal assistive glove for stroke survivors in comparison with the current assistive glove.

MODELING

- Equations of motion were derived for a finger with 3 joints (Fig 2). The model predicts the joint angle trajectories given 4 cable support heights (at the fingertip, and DIP, PIP and MCP joints) and cable tension.

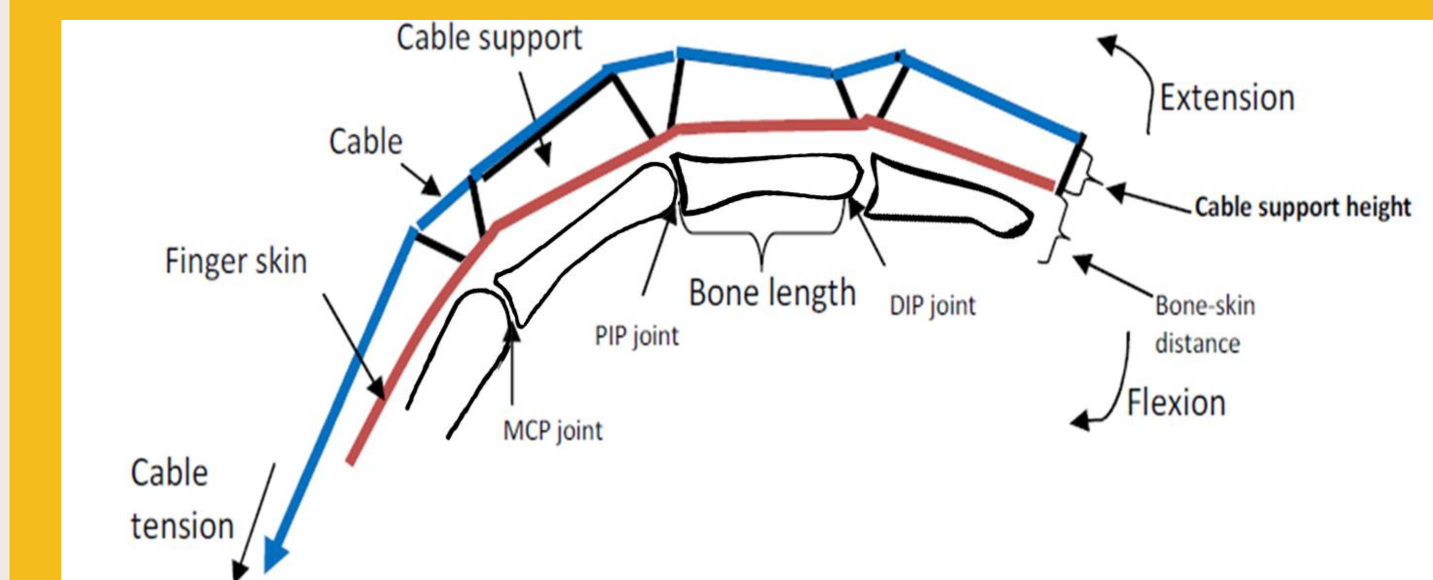

Fig 2. A diagram of a biomechanical model for a finger.

DATA COLLECTION

- Normal hand opening trajectory of a healthy young adult were collected using Optotrak 3D Investigator Motion Capture System.
- DIP, PIP, and MCP joint angles during normal hand opening were computed.

OPTIMIZATION

- Cable support heights and tension were optimized so that the simulated trajectories best resemble the experimental trajectories by minimizing the following objective function:

$$\min\left[\left\|\theta_{DIP,sim}-\theta_{DIP,obs}\right\|+\left\|\theta_{PIP,sim}-\theta_{PIP,obs}\right\|+\left\|\theta_{MCP,sim}-\theta_{MCP,obs}\right\|\right]$$

where $\theta_{DIP,sim}$ is a vector of simulated DIP joint angle and $\theta_{DIP,osb}$ is a vector of experimentally determined DIP joint angle. Same is applied for PIP and MCP joints.

- Gradient based optimization was used ("fmincon")
- Initial condition was set to the current glove parameters.
- Joint stiffness and damping coefficient were set to 0.5 Nm/rad and 0.01 Nm/rad/s, respectively, for all joints of stroke survivors [4].
- Phalanx lengths and weights were set as follows:

	Distal	Middle	Proximal
Length (mm) [5]	19	28	47
Weight (g) [6]	1.2	1.5	4.5

- The optimal cable support heights and tension were compared with the existing glove. The simulated optimal trajectory is shown in Fig 3.
- The existing model COULD NOT fully open the finger.

	Cable Support Height (mm)				Tension (N)	Error (rad)
	Fingertip	DIP	PIP	MCP		
Optimal	10.9	9.0	**29.7**	14.9	**53.2**	**4.4**
Existing	9	9	9	9	250	15.9

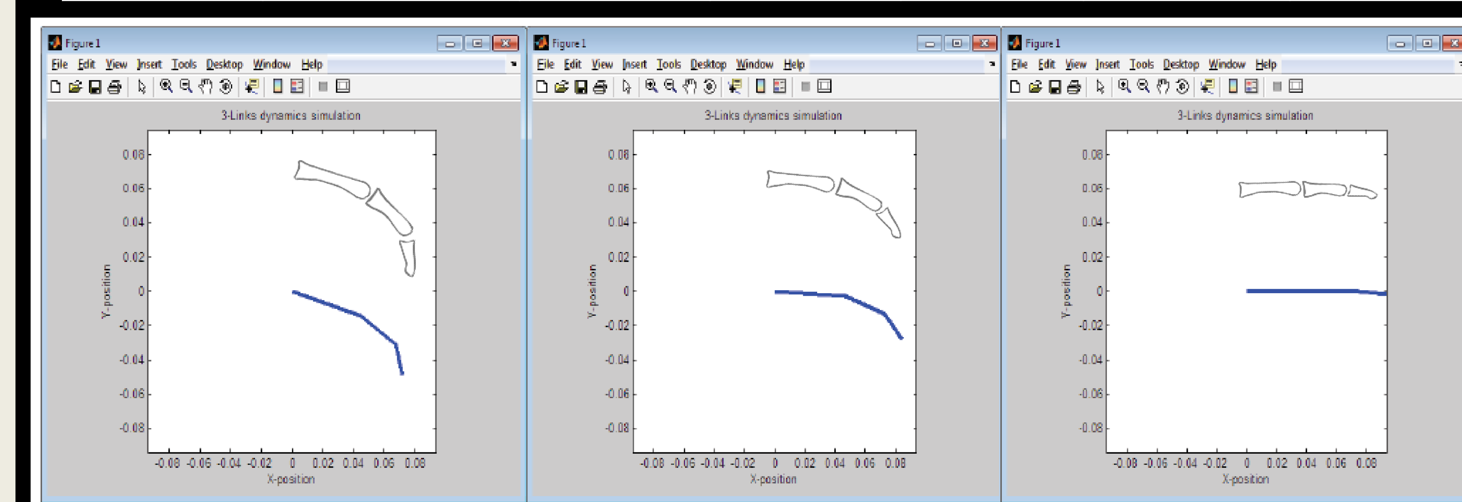

Fig 3. The simulated optimal hand opening trajectory (from partially opened (left) to fully opened (right)).

FUTURE WORK

- The compressive force will be constrained for the comfort level in the future optimization work.
- A prototype glove will be built with the optimal cable support heights and tension.
- Clinical evaluation will be conducted to compare stroke survivors' hand opening trajectories and comfort for the optimal vs. existing gloves.

CONCLUSION

- A cable-driven assistive glove can be modified with the new optimum design parameters for better finger opening assistance and performance for stroke survivors.
- This study demonstrates the potential that biomechanical modeling can be used to optimize design for an assistive device and improve rehabilitation processes.

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