# A robotic exoskeleton for upper-extremity assistance

This work presents an upper-extremity robotic exoskeleton to augment enhanced strength performance for the human operator. This preliminary work is to prove that a wearable biomechanical suit can reduce the metabolic cost of lifting objects in industry, the military, labor-intensive occupations; even rehabilitation for the disabled and everyday use for the elderly. This exoskeleton design differentiates from other projects because other exoskeletons until this time have focused on the lower body extremity [1]. This exoskeleton prototype is also meant as a gateway preliminary model for an opportunity to design a future model that integrates a more complex control system that utilizes sensing methods that could range between EMG muscle activity, brain/machine interfaces, or possibly direct nervous system signal monitoring.

This physical exoskeleton is a wearable tool. This tool encompasses a backpack frame that straps and form fits to the user, a right arm apparatus that acts as an exoskeleton, and a motor and steel cable line system that allows appropriate movement to the focal joints of the arm apparatus increasing the natural muscle torque capabilities at the shoulder and elbow joints.

The scope of this project is large and has many complex and moving parts. It is essential that this project is assembled and tested piece by piece in order to achieve full function to avoid a multiple-part ineffective model. Therefore this project will be completed in phases with the elbow joint being the initial point of interest. The motor-cable system will be tested with a basic fundamental model with all components and variables to take into account including stress tests, frictional constraints, rotational limits, torque capabilities and variation, motor angular velocity and variation via current level, etc. From this stage it will be apparent if the motor/cable system is the appropriate route of action, and if so, move on to the next stage.

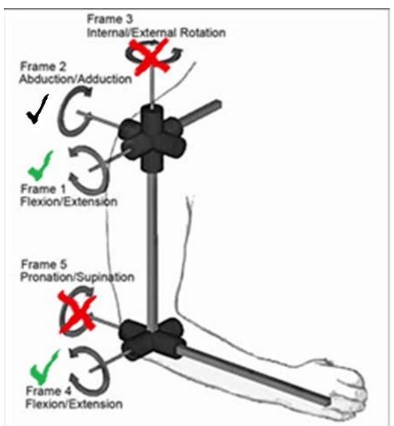



**Figure 1.**
Kinematics diagram of proposed biomechanical model showing frame designation for joints' modeled degrees of freedom.

Kinematic Model: The dynamics of a biomechanical model of the human arm has three major planes of rotation and the elbow has two. Figure 1 represents a three-dimensional model of the rotational movement of the human arm. The red checkmarks indicate what rotational plane will be restricted when wearing the exoskeleton, the black checkmark indicates where the user has free natural rotation (at the deltoid), and the green checkmarks indicate the arm rotations which will be aided by the exoskeleton through the 'cable line system.'

The control system will utilize electrical signals sent from the left hand of the operator via buttons to control the direction of rotation of two DC power window motors which are powered by a lightweight and portable high current battery. Safety and function: There is a kill-switch that opens the circuit and turns off the power to the motors which have high-torque gears designed to resist movement up to 100lb, this allows immediate turn-off and locking for when holding heavy objects.

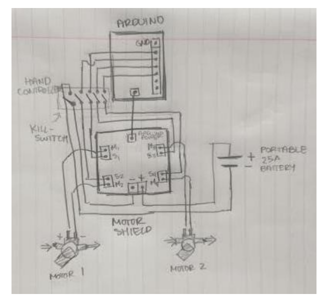
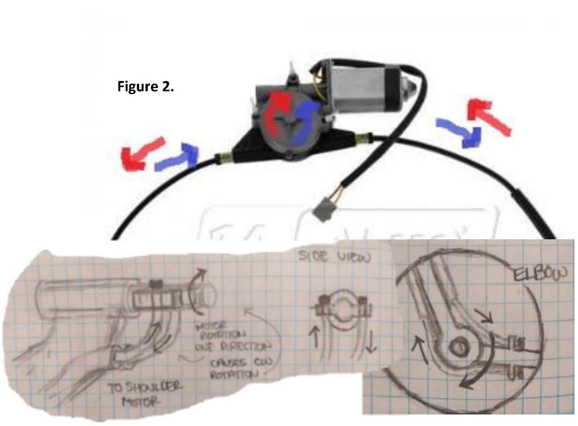


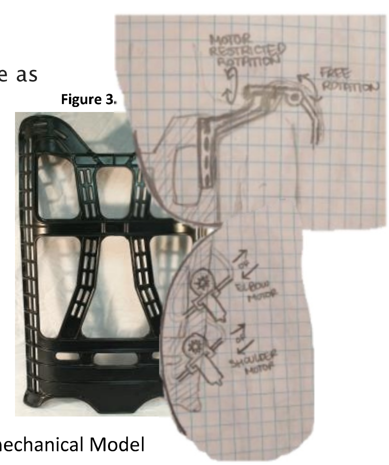

Figure 2.




The steel cable line system acts similarly to bicycle brake lines except in this case instead of linear motion in the handles this system translates to torque rotation of the motor gear that rotates an internal pulley which pulls and pushes a shielded steel cable line. This allows the shielded cables to have minimal volume and wrap around the shoulder, down the arm, and still have function under high-stress conditions. This means two cables (from either end of the motor pulley) will run to the shoulder and the elbow in separate pairs and will translate to rotational movement at the joints (shown in left sketches).

The goal and purpose of this exoskeleton is to take as much weight from the arms and upper-back as possible and distribute the load to the waist. A form-fitting back pack accomplishes this with shoulder and waist straps which are pre-designed to have add-on equipment. This distributes the load from the arm across the appendicular to the axial skeletal system in the upper body, decreasing the metabolic cost in the muscles in just the area of the lift.

Figure 3.




[1] Fleischer, Christian. "Controlling exoskeletons with EMG signals and a biomechanical body model." PhD diss., Scuola Superiore Sant'Anna, pp. 9-23, 2007.
Fig 1. "Dynamic Biomechanical Model for Assessing and Monitoring Robot-assisted Upper-limb Therapy." Dynamic Biomechanical Model for Assessing and Monitoring Robot-assisted Upper-limb Therapy. N.p., n.d. Web. 20 Aug. 2015.
Fig 2. "Dynamic Biomechanical Model for Assessing and Monitoring Robot-assisted Upper-limb Therapy." Dynamic Biomechanical Model for Assessing and Monitoring Robot-assisted Upper-limb Therapy. N.p., n.d. Web. 20 Aug. 2015.
Fig 3. MOLLE Frame - Black - Style 1602 NOS. Digital image. :: Belts, Frames and Shoulder Straps. N.p., n.d. Web. 20 Aug. 2015.