Design of Lightweight and Portable Soft Shoulder Exoskeleton in Community Settings

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***Abstract*— Growing attention to exoskeletons' potential for augmenting human abilities and physical rehabilitation has led to a growth in research in the field of wearable robotics. Upper limb exoskeletons pose a large challenge mainly due to the high complexity of anatomical structures in the upper body and the increase of mobility needed that limits the size and weight of the exoskeleton. In this work, we present an upper limb shoulder exoskeleton that is portable and lightweight to be used in a community setting.**

I. Introduction

Many working age individuals have work-related musculoskeletal disorders that exclude them from the workforce leading to significant socio-economic problems for the individual and society. [1] Upper limb wearable robots have growing industry interest as a solution to reduce the risk of developing musculoskeletal disorder. A major design hurdle upper limb exoskeleton needs to overcome is the anatomical complexity of the upper limbs, and current state of the art upper limb shoulder exoskeletons have been limited to large and tethered exoskeletons that cannot be used in daily lives. Smaller, portable exoskeletons are limited to passive exoskeletons based on spring mechanisms that limit its ability to be used in the variety of activities that is needed in daily life.

II. Mechanical Design

To address the challenges above, we created a lightweight and portable shoulder exoskeleton that can be used in a community. The exoskeleton is a combination of lightweight, rigid carbon fiber rods to transmit forces from the actuator with soft, flexible textile straps that hold the exoskeleton in place to the wearer comfortably. We used the novel paradigm of a quasi-direct drive actuator to provide high torque while having a low gear ratio to reduce the back driving torque. This actuation paradigm provides an advantageous assistance to mass ratio for the exoskeleton while ensuring high compliance. [2], [3] To transfer the force from the actuator to the shoulder joint, a Bowden cable mechanism was used to further reduce the mass penalty since the mass is away from a distal location and in a central location on the waist. A passive, free hinge mechanism and a gravity compensation controller was used to properly apply assistive torque to work in parallel with the human glenoid. This design allows the exoskeleton to provide assistance for both degrees of freedom in the shoulder joint: extension-flexion (sagittal plane), and shoulder abduction-adduction (coronal plane).

Fig. 1 shows are shoulder exoskeleton being used in a variety of activities that is present in daily life.

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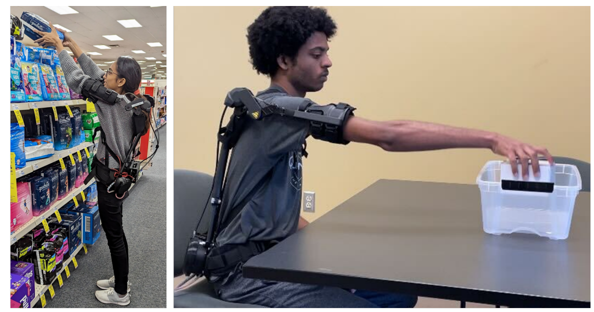

Fig. 1. (A) Our portable exoskeleton can be used outside a clinical setting. The exoskeleton is able to provide assistance to reach and lift a mass over the head. (B) The exoskeleton is able to provide assistance in a variety of manual tasks, such as a forward reach and grab.

A challenge with a Bowden cable system is the backlash that causes major losses in force transmission. To minimize the backlash, we minimized the deflection angle of the cable which minimizes the friction between the cable and the conduit while also applying a pretension force on the cable to further minimize backlash. The overall specification of the exoskeleton can be seen in Table I.

TABLE I

Shoulder exoskeleton specifications.

Specification	Value
Total mass (including battery and wearables)	4.7 kg
Actuation torque	16 Nm
Backdrive (resistive) torque	0.5 Nm (low)
Battery life	3 hrs

III. Results

The biomechanics model-based control allows for high accuracy torque tracking. Data was gathered from a 10 Nm amplitude sine wave reference signal. The root mean square error results in 1.4

References

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