Mechatronic Design of Lightweight and Portable Hip and Knee Exoskeleton: Comfort-Centered Design

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***Abstract*— To overcome human physiological limitation, exoskeletons have been used to for assistive and rehabilitative purposes to improve a person's physical condition. Lower limb exoskeletons, such as the hip and knee, have been developed to provide the wearer walking and squatting assistance. [1] However, one major issue with the implementation of exoskeletons have been the comfort and feel of wearing an exoskeleton. Since exoskeletons directly inject force to its wearer, inappropriate or unexpected forces can cause the loss of assistance and discomfort to the wearer. [2] Thus, in this work, we approached our hip and knee exoskeletons' design from a user-centered perspective which include users' body type, biomechanics, and comfort.**

I. Introduction

Many reasons of why wearable robots, like exoskeletons, are difficult to design and implement originates from the multi-faceted requirements exoskeletons bring. A major challenge is ensuring the wearer's safety and comfort while also maintaining a lightweight design without incurring additional metabolic penalties due to the extra mass exoskeletons introduce. [3] [4] In many cases, the effectiveness of exoskeletons are given the priority thus making the comfort of exoskeletons an after thought. For our both our hip and knee exoskeletons, we based our design on the user's biomechanics, safety, and comfort to determine how the exoskeleton should provide its assistance.

II. Hip Exoskeleton Mechatronics Design

Fig. 1. Breakdown of the mechatronics design of our hip exoskeleton. Singular control box is needed as the electronics and battery is contained within making the mass more central and less noticeable.

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The mechatronic design of our hip exoskeleton can be seen in Fig. 1. The mass of the hip exoskeleton is roughly 3.4kg while being able to provide a peak torque of 18Nm. The exoskeleton's control board and actuators are powered by a 24V battery making the exoskeleton portable with a battery life of approximately 2 hours

III. Knee Exoskeleton Mechatronics Design

Following similar user centered design approach to our hip exoskeleton, our knee exoskeleton design considers the wearer's biomechanics to ensure their comfort. The electronics are placed in a contained area like the hip exoskeleton. Plastic braces are placed in the anterior and posterior of the thigh to better secure the exoskeleton to the wearer while a passive joint on the shank allows the wearer to move freely without a rigid brace hurting the wearer if the brace becomes misaligned with the wearer.

Fig. 2. Mechanical design of our portable knee exoskeleton. The knee exoskeleton was able to provide walking assistance to an elderly subject

IV. Results and Discussions

We tested our hip exoskeleton on four able bodied subjects measuring the metabolic rate reduction, observing the wobbling of the system, and a had the subjects fill a System Usability Scale (SUS) survey. Using a user-centered approach to design our portable hip exoskeleton, we were able to improve the comfort and effectiveness for the wearer.

References

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