Balance Assistance for CMT Disease

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Abstract

The objective of this team's project is to design a balance assistance device for people who are suffering from Charcot-Marie-Tooth (CMT) disease, a nerve disorder that directly affects the muscles in the lower legs and hands. CMT causes a condition called foot drop, which can cause difficulty lifting the foot. Current solutions focus primarily on limiting ankle motion along the sagittal plane, thus neglecting the lateral ankle motion along the transverse plane. The team set out to create a biomechanical device to help solve this secondary issue for patients with this disease.

Introduction

Approximately 126,000 individuals in the United States and 2.6 million people worldwide have CMT disease. The team sees the market potential in this pool of customers in the states and worldwide, and we see that there is a potential for a higher quality product compared to the products that are currently available for consumers with CMT disease. Currently, there are many ankle-foot orthosis (AFO) designs that address foot drop by keeping the lower leg constricted and locked in dorsiflexion, but none of them provide support for lateral movement. Thus, this device will be the first of its kind on the market and could have an enormous economic impact if it became available to the medical industry, especially prosthetics and physical therapy. The design will address foot drop, promote more lateral mobility, and assist with balance.

Design Process

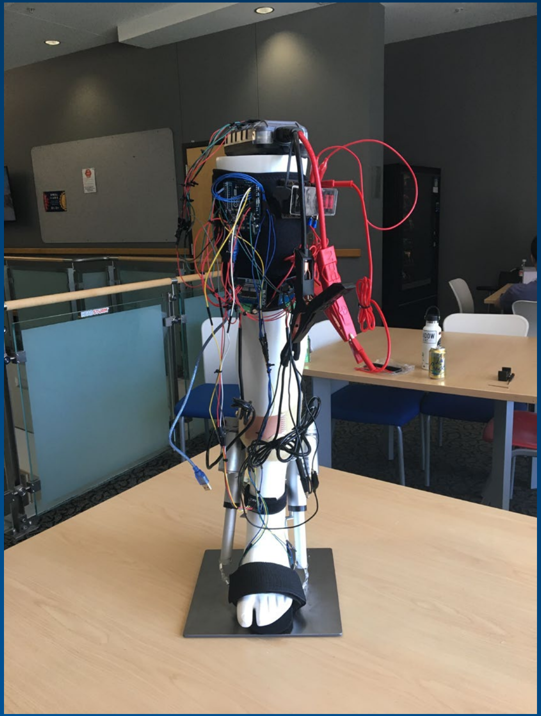
Before beginning the concept design, the team built a list of objectives and constraints to direct the brainstorming process and ensure that all the user's needs would be met. The objectives and constraints served as a guide for the research and design process. Some of the other design objectives included an operation period of 8-hours and minimizing foot drop. Constraints that the team considered included meeting FDA requirements and making the device user-friendly, comfortable, durable, and lightweight. During the brainstorming stage in the Fall of 2020, the team developed a set of preliminary designs to tackle these objectives and constraints. After further research and performing several tradeoff analyses on the preliminary designs, the team settled on a linear actuator model for the device. In the Spring 2021 semester, the team physically built and tested this design to determine if this model was a viable concept. From the team's work in the spring, this model appears to be a viable device with further development.

Project Outcome and Discussion

The first step this semester was to test each piece of equipment separately to ensure nothing ordered was faulty. The linear actuators were tested first, since they are responsible for performing the movement needed to stabilize the user. This task was straightforward; the linear actuators were set up to a motor driver and an Arduino running a simple extension and retraction command. The temperature sensors, pressure sensors, and IMU were connected to an Arduino and tested to check functionality; once we confirmed that the Arduino code worked with the sensors, the sensors were calibrated.

After the testing and calibration of the components proved successful, the team started the assembly of the design. The team decided to initially work with the cheaper, plastic AFO and cut the AFO above the ankle, attaching door stop springs in order to add some degrees of freedom without compromising the ability to prevent foot drop. The linear actuators were the first part mounted to the AFO. The following electronic components were sewn to the thigh brace: two motor drivers (one for each linear actuator) and one Arduino. Three pressure sensors were stuck to a shoe insert and slid into the AFO to determine weight shift. The IMU was sewn onto an ankle strap to indicate the angle of the user’s ankle. The temperature sensors were taped to the battery to alert the user if there was any overheating that could threaten their safety. Once all the electronic components were placed, the whole system was wired.

It took longer than expected to wire and assemble our design, so only basic functionality of the device was feasible with the time constraints.



Recommendations for Future Development

By the end of the semester, we were able to construct a prototype, but not a final design of the project. However, in constructing and implementing functionality for that prototype, we were able to determine the weaknesses in our proposed design as well as potential approaches to future implementations.

After a semester of ensuring that we could reliably wire, write code for, and calibrate linear actuators, our team quickly realized a few key problems that limited what we could accomplish and complicated the functionality of our overall design. The linear actuators, while quick, were limited in how fast they could extend and retract. Their weight and shape made it difficult to mount them onto the AFO and would potentially be cumbersome for the wearer. Finally, our team could not find a way to calibrate the actuators into applying a set amount of force in Newtons. Thus, a beneficial approach for another design team would be to research better linear actuators.

As for improvements to the physical aspects of the AFO, there were a few ideas that our team could not figure out how to implement and/or did not have the time to. The extensive wiring and the three different straps required to put on the prototype device makes it uncomfortable to both put on and wear due to the number of steps required and the weight of all the components. An improved prototype could cut down on the tedium by better organizing the wiring and cutting down on the size of the AFO design. Due to the presence of the strap at the front of the foot, the positioning of the wires, and the cables attached to both the strap and the linear actuators, the AFO cannot be placed inside a shoe, restricting the wearer's ease of use. Potential improvements would be to either rework the linear actuator/cable system, outfit a custom shoe that is part of the AFO, or replace the linear actuators entirely due to the flaws as mentioned above.
The size and weight of the power source necessitated the use of support outside of the AFO in order to hold it, so our team had to decide on allowing it to clip to a belt. A better prototype could utilize a smaller battery of comparable capacity. However, due to the voltage requirements of the linear actuators, a smaller battery may require a different method of applying force to the wearer.

To see video of the device working, please view our video here (https://youtu.be/9c7fjTB0nao)