SOFT PRACTICAL UPPER BODY EXOSKELETON FOR REHABILITATION

EXOSKELETONS AND THEIR IMPLEMENTATION

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Mechanical Engineering

By
Kristen Pettit-Pokora

December 1, 2023

Technical Team Members:
Clara Bender
Madeleine Deadman
Addison Hall
Hannah Rigby

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISORS

Joshua Earl, Department of Engineering and Society

Sarah Sun, Department of Mechanical and Aerospace Engineering

INTRODUCTION

Neuromuscular diseases take over the body in a slow and painful manner. These diseases attack the connections between a persons mind and their ability to control corresponding muscles, leaving those affected with an ever changed way of life. Alongside the physical implications of such diseases, there are a variety of burdens such as chronic pain, life expectancy, economic costs, and quality of life (Carter 2012). In an effort to better lives for those with neuromuscular diseases, assistive technology has been evolving, working towards bringing original bodily functions back to patients.

One primary example of these assistive technologies are exoskeletons. My technical capstone team and I plan to navigate creating a soft exoskeleton focused on providing muscular assistance with one degree of freedom (flexion and extension) at both the elbow and wrist for patients with neuromuscular diseases and post-stroke complications. The intended use is for rehabilitation, with the hopes that some discoveries could provide service to further development in future designs beyond the rehabilitation realm. In addition to the technical project, I will be investigating the sociotechnical complications related to mental health for exoskeletons and their implementation as my Science, Technology, and Society project. By researching for both of these, I hope to gain further insight on exoskeletons and what accompanying advantages and challenges they carry.

In order to understand the sociotechnical complications I will look into answering questions on current groups that use exoskeletons, their caregivers, as well as exoskeleton manufacturers. All of who play a considerable role in exoskeletons usage and their implementation. Some questions I will ask will regard how current exoskeletons are used/what their intended purpose is, any mental burdens associated with their use, and how might their

mental state be before using exoskeletons versus after. These questions will allow me to explore not only the effects and usage of exoskeletons, but also gain a better perspective from those with neuromuscular diseases on what would be best for them.

My Science, Technology, and Society (STS) project and technical capstone project both dealing with exoskeleotons, naturally will have a lot of crossover. With a stress on ensuring users of exoskeleton's mental health is not bogged down by the technology, my technical project will account for this. Ideally to create a technological system that would benefit users biomechanically and mentally.

In this document I will navigate over my technical project to share what my group's plans are in order to try and help patients in rehabilitation. Next I will open up on my STS project by describing what socitechnological issues are currently out there, with regards to exoskeletons. Also in this section will come my research plan with how I will conduct my findings to ensure it is encompassing. Lastly, the STS project portion will discuss the timeline of which I plan to have everything completed by.

TECHNICAL PROJECT

My technical capstone project will focus on creating a soft exoskeleton that will provide one degree of motion (flexion and extension) at both the elbow and wrist for people with neuromuscular diseases and stroke patients that still have some muscle activation. Our goal is to read the muscle response, and translate it to be enhanced by the exoskeleton, so that enough force can be generated for the patient to perform the task of drinking from a glass/bottle. The device will consist of two main modules; one for the upper arm and another for the wrist.

In the upper arm module will be a pneumatic actuator that will act as the elbow flexing to provide the force necessary to act as the contracted muscles. The actuator will be programmed to an Inertial Measurment Unit (IMU) that will track the physical orientation of the arm, an electromyography (EMG) for sensing muscular activity, and an Arduino IDE for compiling the information from the IMU and EMG to directly communicate with the actuator. In the wrist module will also be an IMU and EMG that feed into an Arduino IDE, however the flexion motion at the wrist will be done by an Romote Control (RC) Servo Motor which can rotate a full 360 degrees on its own.

The project's main objectives are to create a light soft wearable exoskeleton while keeping it low cost so it is easily accessible, as well as being mindful of its impact on patients in the rehabilitation realm. "Robotic technology offers new possibilities to address this challenge, but it is critical that devices for independent training are easy and appealing to use," (Lambelet 2020). As Lambelet discusses the benefits of using exoskeletons, he notes the important of its comfort and appeal. These factors will be taken in when designing our capstone project, to create a more well rounded piece of technology. Since at the root of it, the goal is to help patients recover, not hinder it.

STS PROJECT

The central research question for my Science, Technology, and Society (STS) project is how does the implementation and usage of exoskeletons have an effect on the psycological state of its users? There are burdens associated with developing neuromuscular diseases that already have a toll on mental health, so looking into how exoskeletons have an effect on this is something I am interested in researching. The importance of this lies not only in mental health

factor being neglected when creating and implementing technology, but also will open the door for investment in correcting this narrative and providing knowledge on the matter. For many current companies producing exoskeletons, the focus is on the biomechanical improvements of the technology, resulting side effects or potential side effects are not typically mentioned (Kranenborg 2023). Given that many of those with neuromuscular diseases most likely experience some sort of mental health effects prior to using assistive technology, it is important to understand the effects of implementing technology into that realm.

The technology at the center of this project is exoskeletons. There are physical advantages to using them in certain cases, yet when designed without the inclusion of the user, results can be more harmful than good. For many with neuromuscular diseases there is a sense of independence that accompanies the disease, on top of other psycological changes. To properly design an exoskeleton, would include being mindful of these prior mental states and incorporating changes to technology as needed to adjust.

Relevant Social Groups

The three main relevant social groups are users of exoskeletons, caretakers, and exoskeleton manufacturers. Neuromuscular diseases worsen over time, neurodegenerative ones especially, resulting in adapting to not only physical changes, but mental as well. It was reported that alongside patients with such diseases, caregivers also experienced lower depressed mental states as patients conditions decreased (Burke 2017). Caregivers witness patients health worsening which may bring on feelings of anxiety, depression, etc. With that being said, they are a relevant social group that should be looked into given their stake in the matter. Manufacturers producing the devices also have a role in creating and selling the technology, so should be considered as well.

Those at risk for developing neuromuscular diseases, may also be relevant however will be left out for this research, since the focus is on those affected in the rehabilitation stage. Lower age groups may also be excluded, since many neuromuscular diseases typically set in with older age. Though studying those of younger age and at risk for neuromuscular diseases could help in formulating ways about preparing patients' mental prior to being too effected by the disease and using assistive technology.

Frameworks/Methodologies

To navigate researching the topic disability studies and public policy frameworks will be the primary sources of information. Disability studies is at the forefront of the topic, so it will offer a lot of insight with regards to what has been researched already and what areas still needs to be investigated. There are not a lot of policies yet created for exoskeletons since they are relatively new. However, there could be some drafts or general guidelines out there that could help shape the direction with how exoskeletons are being implemented. It might also do good to look into similar assistive technologies, like prosthetics, since they may have some public policies or more research performed on them.

Time Line

In order to research and document my findings, I will need to follow a pretty strict timeline. For initial research to gauge the general stage knowledge of the psycological effects exoskeletons have, I will need a week and a half of sourcing from different articles. Afterwards, will come narrowing down specific articles that attribute the most important information which will take two weeks. Following that, I will analyze the texts and document my research for my thesis project in the spring which will take a couple months. Finally I will produce my thesis paper at the end of the spring.

KEY TEXTS

Burke's article opens the connection between patients and caregivers, showing that both are effected by neuromuscular diseases. Both parties having resulting mental health changes from the varying state of the patient's condition. Which could be used further to investigate the mental state of exoskeleton users prior to using exoskeletons, as well as investigating the extent to which the effects reach target social groups.

"Disease Burden in Neuromuscular Disease: The Role of Chronic Pain" by Carter touches on the mental health of those with neuromuscular diseases and opens up about complications that come with having the disease. There is a big focus on the burdens associated with the diseases such as anxiety, depression, and the grappling feeling of losing something. This text could provide insight as to prior psycological effects that occur prior to any assistive technology being introduced.

To investigate more of the exoskeleton manufacturer's side of exoskeletons, Kranenborg's article delves into this. It discusses side effects of exoskeletons that aren't made appearant when marketing the product only for its physical benefits. How in design, there is more of a focus on the biomechanics of the technology and less on how it can benefit its users socially, economically, or psychologically. With this knowledge, better understanding of how exoskeleton manufacturers think through their designs and implementation plan.

At the start of every disease, is the diagnosis. Which holds an important stake in the mental state of patients in the early on stages. "Neuromuscular diseases: Diagnosis and management," gets into the background of neuromuscular diseases as well as how diagnosing them goes. Which is important when considering the background of these illnesses in order to figure out where exoskeletons should fit in with them if at all.

REFERENCES

Burke, T., Galvin, M., Pinto-Grau, M., Lonergan, K., Madden, C., Mays, I., Carney, S., Hardiman, O., & Pender, N. (2017). Caregivers of patients with amyotrophic lateral sclerosis: Investigating quality of life, caregiver burden, service engagement, and patient survival. *Journal of Neurology*, *264*(5), 898–904. https://doi.org/10.1007/s00415-017-8448-5

Carter, G. T., Miró, J., Abresch, R. T., El-Abassi, R., & Jensen, M. P. (2012). Disease Burden in Neuromuscular Disease: The Role of Chronic Pain. *Physical Medicine and Rehabilitation Clinics of North America*, *23*(3), 719–729. https://doi.org/10.1016/j.pmr.2012.06.004

Kranenborg, S. E., Greve, C., Reneman, M. F., & Roossien, C. C. (2023). Side-effects and adverse events of a shoulder- and back-support exoskeleton in workers: A systematic review. *Applied Ergonomics*, *111*, 104042. https://doi.org/10.1016/j.apergo.2023.104042

Lambelet, C., Temiraliuly, D., Siegenthaler, M., Wirth, M., Woolley, D. G., Lambercy, O., Gassert, R., & Wenderoth, N. (2020). Characterization and wearability evaluation of a fully portable wrist exoskeleton for unsupervised training after stroke. *Journal of NeuroEngineering and Rehabilitation*, *17*(1), 132. https://doi.org/10.1186/s12984-020-00749-4

Mary, P., Servais, L., & Vialle, R. (2018). Neuromuscular diseases: Diagnosis and management. *Orthopaedics & Traumatology: Surgery & Research*, *104*(1, Supplement), S89–S95. https://doi.org/10.1016/j.otsr.2017.04.019