**Thesis Project Portfolio**

# Pneumatically Actuated Soft Wearable Exoskeleton for Upper Limb Motion Rehabilitation

(Technical Report)

# Investigating Tele-Rehabilitation and the Feasibility of Wearable Rehabilitative Devices in a Virtual Environment

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

**Jahnavi Manish Dave**

Spring, 2025

Department of Mechanical and Aerospace Engineering

## Table of Contents

## Executive Summary

### Introduction

In the wearable medical device industry, there remains a clear gap in the availability of upper limb rehabilitation devices designed for home use. Rehabilitation is essential to restore mobility, strength, and coordination for daily independence in patients suffering from upper limb mobility issues. However, upper limb therapy is typically addressed through expensive, clinic-based treatments. For patients in remote areas or with limited financial means, access to such specialized facilities is often unfeasible, resulting in fewer sessions and delayed recovery. Recently, wearable exoskeletons have emerged as tools for accessible upper limb rehabilitation.

For our technical project, my team is designing, testing, and manufacturing a pneumatically actuated soft wearable exosuit tailored for stroke survivors and individuals with neurodegenerative diseases. The goal is to create a portable, user-friendly device that empowers patients to continue therapy without the burden of travel or facility costs. In parallel, my STS research explores the role of tele-rehabilitation with prosthetic and wearable technologies in closing geographic and financial gaps to care. This involves analyzing how healthcare providers, insurance systems, and patients are adapting to telehealth platforms. Together, my technical and STS works aim to make rehabilitation devices not only more functional and convenient, but also more practical and accessible within a broader sociotechnical context, supporting their use as tools for quality rehabilitation in underserved communities.

### Technical Capstone Report Summary

The goal of our technical capstone project is to design and build a soft, wearable upper limb exosuit to support muscle rehabilitation, particularly for patients experiencing mobility loss

due to stroke. Our aim is to create a device that is lightweight, portable, and affordable—making at-home rehabilitation more accessible and practical for a wider population. To generate movement in the arm, the exosuit uses pneumatic actuators that mimic natural muscle functions to assist patients in regaining mobility. Pneumatic actuators use compressed air to create push-pull forces, offering soft, lightweight movement with adjustable actuation speed based on airflow. Although this method requires a mounted air compressor, which can be somewhat bulky and noisy, the benefits in responsiveness and control made it the best fit for our exosuit.

The arm has seven degrees of freedom (DOFs) or directions it can move – three in the shoulder, one in the elbow, and three in the wrist. Our project targets two DOFs in the shoulder by utilizing a rotating shoulder mount integrated into the exosuit's collar. This mount allows patients to reposition the actuator cables from the front to the side of the arm, enabling lateral movements in addition to vertical ones. In addition, the two actuator cables are positioned along the arm (mimicking the triceps muscle) and along the shoulder blades (mimicking the lateral muscle), allowing for full 90-degree range of motion in the shoulder. This design allows for greater adaptability to the user's needs and therapy goals.

**STS Research Paper Summary**

As healthcare becomes increasingly digitized, virtual rehabilitation is emerging as a promising possibility for patient recovery, particularly in rural America where geographic and infrastructural limitations often hinder access to traditional rehabilitation services. This paper uses Actor-Network Theory (ANT) to explore the feasibility of integrating wearable medical technologies, such as exoskeletons and prosthetics, into tele-health systems for rural patients. The study focuses on the dynamic interactions among three key actors: patients, healthcare providers, and insurance companies. Patients, as end-users, face challenges related to digital

literacy, device accessibility, and trust in remote care. Healthcare providers serve as intermediaries, navigating patient needs while contending with clinical standards, policy constraints, and insurance requirements. Insurance companies, acting as financial gatekeepers, establish reimbursement frameworks that significantly influence the adoption and scalability of wearable devices in tele-rehabilitation.

By investigation the interactions among these actors – such as inconsistent coverage policies, provider hesitancy toward adopting tele-rehabilitation tools, and patient concerns over cost and usability – this paper investigates the potential for broader tele-rehabilitation programs. In addition, mapping these interdependencies serves to understand how tele-rehabilitation, supported by wearable medical devices could address systemic barriers and expand access to specialized care in rural regions. If successfully integrated, these technologies have the potential to lower long-term healthcare costs, enhance recovery outcomes, and transform rehabilitation into a more inclusive and efficient process.

**Concluding Reflection**

Working on both the technical capstone project and the STS research paper in parallel offered a unique experience that allowed me to learn about rehabilitation technology from both an engineering and sociotechnical perspective. Had I pursued these projects separately, I would have focused exclusively on mechanical optimization in the exosuit design, without fully considering the real-world barriers to implementation for my technical capstone exosuit design. Similarly, my STS research would have remained abstract without the hands-on experience of building a device that addressed these challenges. Ultimately, working on both projects together taught me to think more holistically about engineering solutions and how to combine technical feasibility with social practicality.