# Soft Pneumatic Exosuit for Shoulder Assistance in Individuals with Amyotrophic Lateral Sclerosis

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***Abstract*—Amyotrophic lateral sclerosis (ALS) leads to severe upper limb weakness, significantly limiting independence in daily activities. Existing robotic exoskeletons are often rigid, bulky, and restrictive, making them impractical for everyday use. This study presents a soft, pneumatically actuated exosuit designed to provide lightweight and adaptive shoulder support while maintaining mechanical transparency. The system utilizes a Y-shaped textile-based pneumatic actuator, controlled by a real-time gravity compensation algorithm, to modulate assistance based on user movement detected via inertial measurement units. Benchtop evaluations demonstrate that the exosuit delivers up to 8 Nm of assistive torque with a response time under 10 ms, effectively supporting shoulder elevation while preserving voluntary motion when unpowered. Future work will focus on human trials to assess real-world efficacy, refine control strategies, and extend assistance to additional joints. This exosuit represents a promising step toward practical, user-friendly assistive solutions for individuals with ALS.**

***Index Terms*—Soft wearable robot, Pneumatic exosuit, Amyotrophic lateral sclerosis, Upper limb assistance.**

## I. Introduction

Amyotrophic lateral sclerosis (ALS) is a progressive neurodegenerative disease that leads to severe muscle weakness and loss of motor function, particularly affecting the upper limbs [1], [2]. This decline significantly limits independence in activities of daily living (ADLs), necessitating assistive solutions that can effectively support residual motor function. State-of-the-art exoskeletons are predominantly rigid, bulky, and restrictive, making them unsuitable for everyday use by individuals with ALS [3], [4]. Moreover, the complex biomechanics of the shoulder joint pose a substantial challenge for traditional exoskeletons, which often fail to provide seamless, naturalistic assistance [5], [6]. To address these limitations, we present a soft, pneumatically actuated exosuit that offers lightweight, portable, and individualized support for shoulder movement, enabling functional restoration while maintaining mechanical transparency when unpowered.

## II. Methods

The proposed exosuit leverages a Y-shaped textile-based pneumatic actuator, positioned under the armpit and anchored at both the trunk and upper arm, to provide dynamic shoulder elevation assistance. The actuator is fabricated from thermoplastic polyurethane (TPU)-coated nylon, and combining high tensile strength with airtight properties, ensuring durability and comfort (Fig. 1). The actuation system is controlled by a real-time gravity compensation algorithm, which modulates actuator pressure based on the user's volitional movement, detected via inertial measurement units (IMUs) placed on the upper arms and torso. A portable waist-mounted control unit houses the compressor, reservoir, and proportional valves, allowing for untethered operation with minimal added weight (100 g per limb, total system weight: 2.8 kg). The system is designed to be user-friendly, requiring minimal training, with an intuitive adaptive control scheme that seamlessly augments the user's residual motor function.

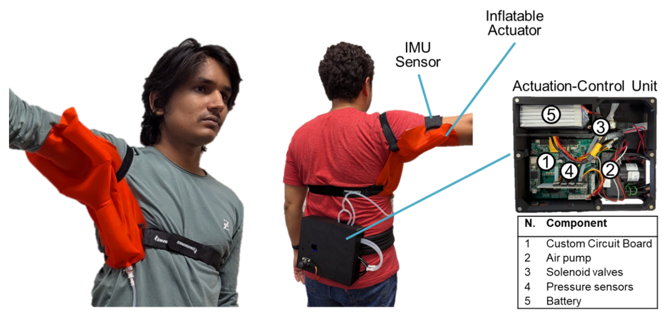


Fig. 1. Overview of the developed soft exosuit for shoulder assistance, composed of a textile inflatable actuator and a portable actuation-control unit.

## III. Results and Conlusion

Two evaluate the performance of the designed pneumatic exosuit, we conducted a benchtop evaluation to assess its torque generation and mechanical transparency. Characterization tests demonstrated that the system provides up to 8 Nm of assistive torque, covering over 50% of the gravitational torque required to fully support an elevated arm (Fig. 2).

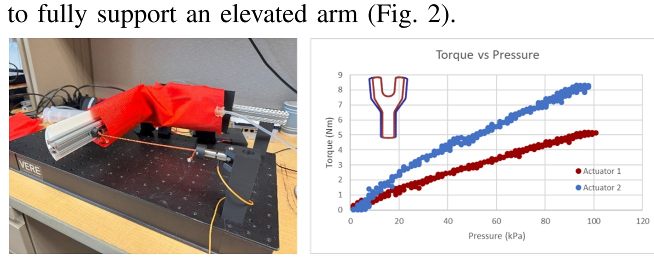


Fig. 2. Benchtop characterization of the soft actuator. On the right, the torque performances of two different actuators are compared, indicating that the shape and size of the actuator affect the assistance capabilities of the exosuit.

To ensure intuitive user interaction, the exosuit employs a gravity compensation controller, which detects residual volitional movement of the wearer using wearable motion sensors, specifically inertial measurement units (IMUs) placed on the upper arms and torso. The system continuously estimates the user's intended movement and adjusts actuator pressure accordingly, providing just the right amount of assistance to supplement rather than replace natural muscle function. The control system exhibited a response time of under 10 ms to seamless adaptation to user movement, while the full deployment of assistive torque occurred within 1.8 seconds.

## IV. Future Work

Following benchtop testing, the next phase of research will focus on human trials to evaluate the exosuit's effectiveness in real-world applications. Initial tests will be conducted on able-bodied participants to refine control strategies, followed by trials involving ALS individuals, assessing improvements in ADLs, fatigue reduction, and user adaptability. Additionally, efforts will be made to enhance system ergonomics, develop personalized actuator configurations, and integrate mobile application-based control interfaces for real-time performance monitoring. Future studies will also investigate multi-joint assistance, extending the exosuit's capabilities to the elbow and wrist, further expanding its potential as a comprehensive wearable assistive solution for individuals with neuromuscular impairments.

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