

PASSIVE EXO SKELETON FOR KNEE

1. **Aditya pavan goud¹, Durga prasad ², Vara Prasad Reddy³, Arun Kumar⁴, Mahesh Chary⁵**
 2. **Godavarthy Krishna Teja ⁶, Tareeq Zaid ⁷**

¹ Student, Department of Mechanical engineering, Vardhaman College of Engineering

² Student, Department of Mechanical engineering, Vardhaman College of Engineering

³ Student, Department of Mechanical engineering, Vardhaman College of Engineering

⁴ Student, Department of Mechanical engineering, Vardhaman College of Engineering

⁵ Student, Department of Mechanical engineering, Vardhaman College of Engineering

⁶ Assistant Professor, Department of Mechanical engineering, Vardhaman College of Engineering

⁷ Assistant Professor, Department of Electronics and Communication engineering, Vardhaman College of Engineering

1. Abstract

In recent years, there has been a growing need for assistive devices that support patient recovery following lower limb injuries or surgeries. The proposed mechanical knee exoskeleton is a non-powered, passive support system designed to aid patients during rehabilitation exercises. Built using a knee brace integrated with a gas spring, this exoskeleton provides controlled resistance and assistance during knee flexion and extension movements. The system does not require any electronic components, making it cost-effective, lightweight, and easy to operate. The primary objective is to enhance joint stability and movement efficiency while reducing muscle strain. Initial testing has shown promising results in supporting leg motion and promoting consistent recovery sessions. The device is suitable for use in both clinical and home-based rehabilitation settings. This paper discusses the design, working principle, methodology, and potential improvements of the knee exoskeleton, emphasizing its relevance as a practical solution for physical therapy applications.

2. Introduction

Knee injuries and post-surgical recovery often require extensive physiotherapy to restore function and mobility. Traditional rehabilitation methods rely on manual therapist support and patient effort, which can be inconsistent and physically taxing. Recent developments in wearable rehabilitation devices have introduced robotic and powered exoskeletons; however, these solutions are often expensive and complex. To address the need for an affordable and easy-to-use alternative, this paper presents a mechanical knee exoskeleton designed to assist patients during recovery exercises. The proposed system consists of a knee brace fitted with a gas spring that provides mechanical support to the knee joint. It assists in guiding and stabilizing knee movements while reducing the load on the patient's muscles. The design emphasizes simplicity, modularity, and user comfort, making it suitable for patients in varied recovery stages. This introduction outlines the motivation behind the project, the clinical need for such a device, and the approach taken to deliver a practical solution. The following sections detail the literature backing the design, the methodology followed during development, and the outcomes observed during preliminary testing.

3. Literature Review

Wearable exoskeletons for rehabilitation have been explored extensively in recent years due to their ability to support physical recovery. Research by Dollar and Herr (2008) highlighted the importance of ergonomic, lightweight exoskeletons for joint support. These devices were primarily designed with motorized components to replicate natural limb movement. Bae et al. (2015) advanced this by developing soft robotic suits using

actuators to assist motion. However, such designs are limited by their complexity and power requirements. Passive exoskeletons, on the other hand, offer a simpler alternative. Yamamoto et al. (2013) proposed a spring-loaded device that provided resistance to joint motion, aiding recovery without requiring electricity. These systems are not only more affordable but also easier to maintain and more accessible to patients. The concept of using gas springs for joint support has also been explored in industrial and ergonomic applications, showing promising results in reducing muscular effort. However, literature on its use specifically for knee rehabilitation remains limited, presenting a research gap. This project aims to bridge that gap by implementing a gas spring-based knee exoskeleton that is fully mechanical. The review highlights the effectiveness, limitations, and design considerations of past studies, justifying the choice of a passive system in this work.

4. Methodology

The development of the knee exoskeleton followed a systematic approach focused on creating a simple, affordable, and mechanically effective rehabilitation aid. The methodology involved the following key stages:

- **A. Problem Identification**

Knee rehabilitation typically requires consistent support and guided motion to help patients recover mobility. Traditional physiotherapy may not always provide consistent assistance, especially in home-based settings. This project aims to develop a mechanical exoskeleton that offers **controlled support using a gas spring**, helping reduce strain on the knee joint during recovery exercises.

- **B. Concept Design**

A passive exoskeleton model was chosen to avoid the complexity of electronics and motors. The concept relied on:

- A **rigid knee brace** to provide structural support around the leg.
- A **gas spring** to generate resistive and assistive force during knee flexion and extension.
- **Support frames and mounting brackets** to hold the assembly securely in place.
- **C. Component Selection**

The following components were selected based on mechanical requirements, availability, and cost:

- **Knee brace** – custom-fit to the patient's leg to ensure comfort and stability.
- **Gas spring** – selected based on required force output and stroke length, positioned to aid in both flexion and extension.
- **Mounting frame and clamps** – designed to fix the gas spring in a mechanically favourable orientation.
- **Straps and cushioning** – used to ensure wearer comfort and minimize pressure points during use.
- **D. Fabrication and Assembly**

The frame and brace were fabricated using lightweight materials such as aluminium and ABS plastic. The gas spring was securely mounted on the side of the knee brace using adjustable brackets. The entire assembly was designed to be modular and adjustable to fit different users.

- **E. Testing and Evaluation**

- Range of motion support
- Comfort during walking and seated leg exercises
- Effectiveness of the gas spring in assisting movement

(a) Example Block Diagram:

[User Initiates Movement] → [Knee Brace literature review for Engagement] → [Gas Spring Activation] → [Controlled Resistance Applied] → [Assisted Knee Motion] → [Reduced Strain] → [Improved Recovery]



5. Conclusion

The mechanical knee exoskeleton presented in this paper offers a viable solution for supporting patients during rehabilitation without the need for electrical components. Its design is centered around user comfort, mechanical simplicity, and functional effectiveness. By integrating a gas spring into a knee brace frame, the exoskeleton provides passive support and resistance, which can be instrumental in reducing strain on recovering muscles and joints. Initial testing demonstrated that the device aids in guided knee motion, which is critical for post-injury or post-surgical therapy. Unlike powered exoskeletons, the proposed solution is cost-effective, easy to maintain, and suitable for deployment in both clinical and home environments. This makes it especially relevant in settings with limited access to advanced rehabilitation facilities. The project successfully meets its aim of delivering a practical and affordable aid for knee recovery exercises, and serves as a foundation for further enhancements in wearable rehabilitation technology.

6. Future Scope

While the current design of the knee exoskeleton offers several advantages, there are opportunities for improvement and expansion. Future developments could focus on integrating sensors to monitor joint angles and movement patterns, providing real-time feedback to both patients and therapists. This would help personalize recovery exercises and track progress more accurately. Lightweight composite materials could be introduced to further reduce the device's weight and enhance portability. Adjustable gas springs or modular resistance settings can make the device suitable for various stages of recovery and different patient needs. Additionally, the inclusion of quick-release mechanisms and universal sizing can improve user experience and accessibility. Collaboration with medical professionals for long-term clinical trials would also help validate its effectiveness and optimize design parameters. In the long term, this mechanical exoskeleton concept could be adapted for other joints such as elbows or ankles, extending its use in musculoskeletal rehabilitation. These advancements would strengthen its potential as a comprehensive, low-cost, and scalable solution in physical therapy.

7. References

- [1] Dollar, A. M., & Herr, H. (2008). Lower extremity exoskeletons and active orthoses: Challenges and state-of-the-art. *IEEE Transactions on Robotics*, 24(1), 144-158.
- [2] Bae, J., De Rossi, S. M. M., O'Donnell, K., Hendron, K., Holt, K. G., & Walsh, C. J. (2015). A soft exosuit for assisting human locomotion using textile-based actuation. *IEEE International Conference on Robotics and Automation*.
- [3] Yamamoto, K., Hyodo, K., Ishii, M., & Matsuo, T. (2013). Development of a passive assistive device for knee joint motion using a spring mechanism. *Journal of Biomechanical Engineering*, 135(11), 114502.
- [4] Liu, M., Wang, Z., & Kim, J. (2020). A review on lower limb rehabilitation exoskeletons. *Robotics*, 9(4), 102.

