JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

EMG Controlled Robotic Glove for Rehabilitation

[1]DISHA R, [2]KHUSHI R, [3]KRUTHI M, [4]MEGHANA K, [5] MR.S CHRISTO JAIN

[1] Student, [2] Student, [3] Student, [4] Student, [5]Assistant Professor
DEPARTMENT OF ELECTRONICS AND ENGINEERING. KS INSTITUTE OF TECHNOLOGY, RAGHUVANAHALLI, BENGALURU, INDIA

Abstract : Electromyography (EMG)-controlled robotic gloves offer a promising approach to assist hand movement during rehabilitation for individuals with impaired hand function. This project presents the design and implementation of a wearable robotic rehabilitation glove that uses surface EMG signals to detect muscle activity and initiate assisted finger movement. The proposed system comprises a two-channel EMG acquisition unit, an ESP32 microcontroller for signal processing and control, and five servo motors connected to a tendon-driven finger mechanism. The system processes the acquired EMG signals and compares them with an experimentally determined threshold to identify the user's movement intention. Based on the detected muscle activity, the corresponding servo motor is activated to provide assisted finger movement. A lightweight glove with 3D-printed mechanical components integrates the sensing and actuation mechanisms into a wearable system. The project also includes a rehabilitation support application, RehabEase, for exercise and progress tracking. The developed prototype was evaluated through EMG signal testing, movement detection, servo response, and integrated finger-movement trials. The project aims to develop a low-cost, portable, and user-controlled rehabilitation system that can provide assisted hand movement while supporting regular rehabilitation exercises.

Keywords—EMG, robotic glove, hand rehabilitation, surface electromyography, signal processing, ESP32, servo motor, tendon-driven mechanism, assistive robotics.

I. INTRODUCTION

Hand movement impairment caused by stroke, paralysis, or neuromuscular disorders can significantly affect a person's ability to perform daily activities. Regular rehabilitation is important for improving hand movement and coordination; however, conventional rehabilitation requires continuous supervision and repeated exercises.
Electromyography (EMG) provides a noninvasive method for detecting muscle activity using surface electrodes. The detected signals can be processed to identify the user's movement intention and control assistive devices. This makes EMG suitable for rehabilitation systems that assist based on the user's own muscle activity.
Robotic gloves can assist finger movements during rehabilitation exercises. However, practical implementation involves challenges such as EMG signal noise, variations in muscle activity, electrode placement, reliable movement detection, and mechanical integration.

Complex control techniques may also increase system costs and implementation requirements.

This study presents the design and implementation of an EMG-controlled robotic glove for hand rehabilitation. The proposed system uses two-channel EMG sensing, an ESP32 microcontroller, threshold-based signal processing, five servo motors, and a tendon-driven mechanism to provide assisted finger movement. We developed a wearable glove with 3D-printed components and the RehabEase application for rehabilitation exercises and progress tracking. The prototype was evaluated through EMG signal testing, movement detection, servo control, and integrated finger-movement trials.

II. RELATED WORK

Research on robotic and EMG-controlled rehabilitation gloves covers soft pneumatic and fabric-based actuation, tendon-driven mechanisms, EMG- and EEG-based intention detection and gesture classification, and fatigue-adaptive control. The reviewed studies are summarized as follows:

1. This study provides a comprehensive review of soft robotic gloves (SRGs) and functional electrical stimulation (FES) for post-stroke hand rehabilitation. It highlights their potential to restore activities of daily living (ADLs) for patients. The study systematically examines recent progress in actuation, sensing, and control mechanisms. It concludes that while hybrid systems show great promise in overcoming individual limitations, critical hurdles remain. Specifically, challenges in portability and wearability continue to be major barriers. These factors must be addressed for future development and real-world deployment.

2. This study introduces a dual-action fabric-based soft robotic glove engineered specifically for ergonomic hand rehabilitation. The design utilizes advanced CNC heat sealing techniques to create symmetrical chamber actuators. These specialized actuators maximize finger contact area during operation. Through this method, the research directly addresses persistent clinical utility challenges. These challenges include customization requirements and achieving an optimal ergonomic fit. Ultimately, it provides a comfortable and effective solution for both flexion and extension assistance.

3. This study focuses on the detailed analysis and development of modular elements for a tendon-actuated glove. The system relies on the implementation of twisted string actuators (TSAs). The research methodology investigates the complex kinematic relationships between tendon-driven actuators and natural hand motion. The study concludes that modular TSA-driven systems

provide exceptional performance benefits. They offer precise actuation necessary for effective therapy. Furthermore, they deliver the high adaptability required to meet diverse rehabilitation needs of individual patients.

4. This study describes an innovative system that transforms low-cost commercial pneumatic gloves into advanced vision-guided assistive orthoses for stroke rehabilitation. The design integrates wrist-mounted cameras with edge-computing capabilities. By operating independently of muscle signals, this study achieved an impressive 96.73% grasp classification accuracy. This methodological approach offers a solid technical foundation for providing accessible assistance. This enables context-aware upper-limb support features. Consequently, it could greatly benefit populations that are typically excluded from expensive EMG-controlled devices.

5. This paper describes a unique textile robotic glove featuring integrated pneumatic actuators. These actuators were fabricated using a specialized ruffling technique. This technique ensures high performance regarding blocking force and bending capabilities. A participant study utilizing EMG sensing was conducted to evaluate the device. The study confirmed that the system prioritizes both safety and user comfort. It effectively guides the user's hand to the desired positions, validating its use for daily activities and post-stroke rehabilitation.

6. This study demonstrates the overall viability of a fabric-based soft robotic glove. The device is equipped with bidirectional actuators designed to assist patients with chronic stroke. It specifically targets individuals with significant hand impairments. Clinical tests involving eight participants were performed to validate its functionality. The results showed significant improvements in manipulating objects during activities of daily living (ADL) tasks. Participants also reported increased confidence and reduced reliance on external support while using the device.

7. This study explores advanced 'assist-as-needed' control strategies for soft robotic gloves. The control framework is based on accurate human–object contact estimation. By utilizing a neural network, the system estimates muscle strength directly from the EMG signals. This study implements a collaborative control scheme where users and robots share workloads. This cooperative approach is applied specifically during complex grasping tasks. Ultimately, it proves to be much more effective for active rehabilitation than traditional passive methods.

8. This study proposes a novel sensor fusion method for hand pattern recognition. The approach combines EMG data with kinematic features gathered using a Leap Motion sensor. It was designed specifically to improve gesture recognition in post-stroke patients. Comprehensive testing was conducted on both stroke survivors and healthy participants. The results demonstrated that fusion-based recognition significantly outperformed traditional single-signal methods. The system achieved an average accuracy of 83%, providing a more reliable control mechanism for wearable hand robots.

9. This study proposes an EMG-driven machine learning control scheme. It was implemented in a compliant actuated robotic glove system. The core methodology utilizes machine-learning algorithms to accurately estimate motion intent. Empirical results obtained from healthy participants were analyzed. The findings suggest that active assistance effectively reduces the muscular effort required. This reduction helps users reach medium-high grasp forces, proving that precise closed-loop control is achievable in flexible and soft robotic systems.

10. This study introduces an advanced EMG gesture recognition system. The architecture utilizes flexible high-density sensor arrays. It combines these sensors with brain-inspired high-dimensional (HD) computing methods. The system successfully combats common issues related to biological signal variability. It achieves an impressive 96.64% classification accuracy across multiple days of testing. This performance proves that robust, flexible, and wearable interfaces can maintain high reliability for human-machine interaction.

11. This study proposes a fabric-based soft exoskeleton glove. The design relies on motor-tendon actuators controlled by an Arduino Nano and PI algorithms. The prototype was tested using both EMG signals and remote inputs. These inputs successfully support controlled finger flexion and extension movements. The key findings highlight the glove's lightweight, affordable, and comfortable design. Ultimately, it enables individuals with impaired grasping abilities to perform daily activities effectively.

12. This study provides a detailed description of an innovative rehabilitation glove. The system incorporates electro-permanent magnets (EPMs) to provide a customizable resistance. This resistance is applied dynamically during the rehabilitation exercises. EMG validation tests confirmed the operational effectiveness of the device for multiple tasks. These tasks include flexion, extension, pinching, and abduction movements. The study concluded that the glove is portable, inexpensive, and significantly enhances patient compliance through adjustable resistance tailored to clinical needs.

13. This study introduces a sophisticated hybrid interface system. The design combines both EMG and EEG signals. It utilizes Bayesian fusion methods alongside fatigue estimation via k-NN algorithms. Tested extensively on healthy participants, the system achieved high overall accuracy. Specifically, it reached 94.5% accuracy while maintaining performance under physical fatigue. This demonstrates strong potential for stroke rehabilitation by ensuring robust intention detection in challenging conditions.

14. This study provides a comprehensive description of a dual-mode wrist exoskeleton system. The device dynamically switches between sEMG-based and EEG-based controls. This switch is triggered automatically when muscle fatigue is detected. By using Boruta feature selection and CNN models, the fatigue detection accuracy of the system was improved. It successfully maintained approximately 80% motion intention recognition rate. This adaptive approach supports prolonged rehabilitation sessions by directly responding to patient fatigue.

15. This study provides a detailed description of an EMG-based gesture classification system. The setup utilizes an armband to capture biological signals. It integrates Model Predictive Control (MPC) to drive a mechanical exoskeleton. The system dynamically adapts its assistance levels based on real-time muscle fatigue. This capability enables highly repetitive and task-oriented rehabilitation training. The experimental results show that MPC-driven exoskeletons can provide progressive rehabilitation tailored to individual patient needs.

16. This study provides a thorough description of a specialized rehabilitation glove. The device incorporates bidirectional pneumatic actuators. It is designed specifically to assist stroke patients in performing activities of daily living (ADLs). Clinical testing demonstrated significant improvements in object manipulation capabilities. Furthermore, it boosted patient confidence during daily tasks. Ultimately, the study validates fabric-based soft robotics as a viable assistive technology for restoring hand function in chronic stroke patients.

17. This study presents an advanced system combining EMG features with kinematic data. Kinematic data were gathered using Leap Motion sensors. This combination is designed to improve overall hand pattern recognition. By employing both feature fusion and decision fusion methods, the system achieved impressive results. It reached approximately 96% accuracy while remaining robust under noise or EMG channel failure. This demonstrates the clear effectiveness of multimodal fusion for reliable rehabilitation robotics.

18. This study describes the development of a neural-network-based classifier. The classifier uses Bayesian and recurrent models to interpret sEMG signals. It is integrated directly with a shape-memory alloy-actuated robotic glove. Through this combination, the system achieved an outstanding 98.7% gesture recognition accuracy. Their work highlights the technical feasibility of real-time adaptive rehabilitation gloves. These devices can be efficiently driven by advanced sEMG-based gesture classification.

19. This paper reviews a wide variety of robotic glove designs. The evaluated technologies include tendon-driven, pneumatic, exoskeleton, and linear actuator systems. The authors analyzed the underlying materials, actuation methods, and control strategies. They placed strong emphasis on the importance of lightweight, low-cost, and portable designs. Additionally, the review highlighted the crucial role of EMG-based control. It also discussed virtual reality (VR) integration in enhancing overall rehabilitation outcomes.

20. This research provides a comprehensive editorial overview of recent technological advances. It focuses on EMG and EEG-based control strategies for assistive robotics. The authors summarized multiple studies covering sEMG feedback methods. They also reviewed CNN-based gesture recognition, transformer-based models, and hybrid approaches. The editorial emphasized the significant promise of biosignal-driven control systems. It also noted persistent challenges regarding system robustness and clinical validation.

A Research Gap

The reviewed studies cover soft pneumatic and fabric-based gloves, tendon-driven and modular actuation, EMG- and EEG-based intention detection, and fatigue-adaptive control. Several of them rely on pneumatic actuation, vision-based control, or machine-learning and multi-signal control schemes, and one study noted that EMG-controlled devices can be expensive. To the best of our knowledge, none of the summarized works combines
(i) two-channel surface EMG sensing with threshold-based movement-intention detection,
(ii) ESP32-based signal processing and control, (iii) five servo motors driving a tendon-driven finger mechanism, and (iv) a companion application for exercise and progress tracking in a single wearable unit. This is the gap that the proposed glove is designed to fill.

III. Problem Identification

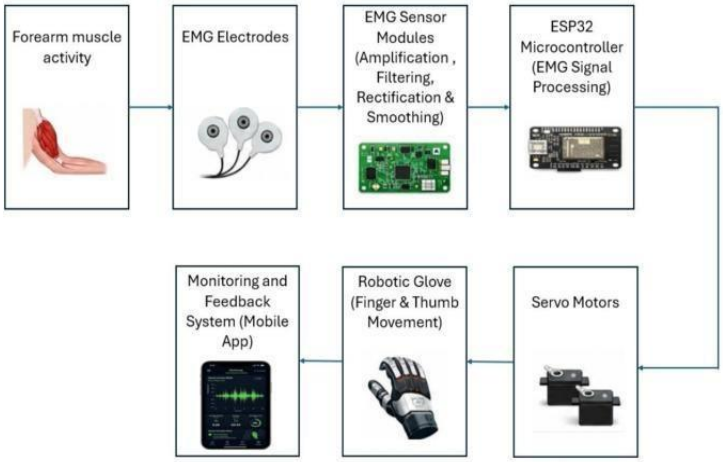
Hand movement impairment caused by stroke, paralysis, or neuromuscular disorders limits a person's ability to perform daily activities, and conventional rehabilitation requires continuous supervision and repeated exercises. Robotic gloves can assist finger movements; however, portability, wearability, ergonomic fit, and customization remain barriers to real-world use.
On the sensing side, EMG-based control faces EMG signal noise, variations in muscle activity, electrode placement, and the need for reliable movement detection. Complex control techniques may also increase system cost and implementation requirements, and one reviewed study noted that expensive EMG-controlled devices exclude many potential users. Some existing gloves operate independently of the user's muscle signals; therefore, the assistance is not driven by the user's own movement intention. Therefore, a low-cost, portable, user-controlled glove that combines simple EMG-based detection with tendon-driven actuation and exercise tracking is needed.

IV. Objectives

The objectives of this work are to:

- Design and develop a lightweight wearable glove with 3D-printed components, in which five servo motors drive the fingers through a tendon-driven mechanism.
- Acquire surface EMG signals through a two-channel acquisition unit and detect the user's movement intention using an experimentally determined threshold;
- Use an ESP32 microcontroller for signal processing and control, so that the corresponding servo motor is activated when muscle activity is detected.
- Develop the RehabEase application for rehabilitation exercise and progress tracking; and
- Evaluate the prototype through EMG signal testing, movement detection, servo response, and integrated finger movement trials.

V. System Architecture / Block Diagram



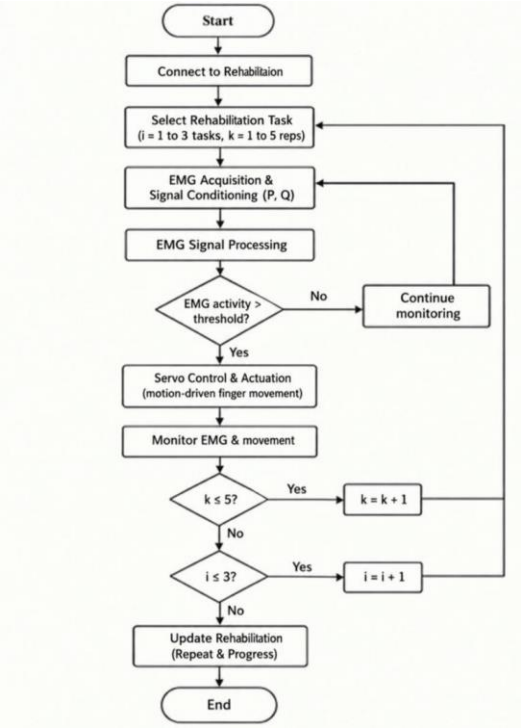
Block Diagram Description

The proposed system is an EMG-controlled robotic glove designed to assist in finger movement during hand rehabilitation. The system detects muscle activity in the user's forearm using surface EMG electrodes. The acquired signals were conditioned by the EMG sensor modules through amplification, filtering, rectification, and smoothing before being provided to the ESP32 microcontroller.

The ESP32 processes the EMG signals and detects the user's movement intention based on the processed signal and the defined control logic. When the required muscle activity was detected, the ESP32 generated control signals for the servomotors. Five servo motors were connected to the fingers through a tendon-driven mechanism, where the servo rotation produced tendon pulling and assisted the corresponding finger movement.

The robotic glove integrates sensing, control, and mechanical components into a wearable system. The RehabEase application provides additional support for rehabilitation exercises and progress monitoring. Thus, the proposed system combines EMG sensing, embedded signal processing, motor control, and mechanical actuation to provide user-controlled assistance during hand rehabilitation.

VI. Flow Chart



Flow Chart Description

The workflow of the rehabilitation glove system is organized into a structured sequence managed through the RehabEase platform. Once connected, the user selects a rehabilitation task consisting of several repetitions. Muscle activity is then acquired using a two-channel EMG setup, and the signals are conditioned through amplification, filtering, rectification, and smoothing. These processed signals are analyzed by the ESP32 microcontroller, which checks whether the EMG activity exceeds a predefined threshold. If the threshold is met, control commands are generated to drive the servo motors, actuating the tendon-driven glove mechanism to assist finger movement. If not, the system continues monitoring until valid activation occurs. Throughout the process, EMG activity and glove movement are continuously monitored to ensure accuracy and safety. The system iterates through repetitions within each task, updating counters until all repetitions and tasks are completed. Finally, the results and progress are recorded in the RehabEase platform, providing feedback for both patients and therapists. This structured workflow ensures reliable, repeatable, and intention-based assistance for hand rehabilitation exercises.

VII. Expected Benefits And Limitations

Expected Benefits

The proposed glove is intended to provide assisted finger movement triggered by the user's own muscle activity, which keeps the user in control of the rehabilitation exercise. Threshold-based processing on an ESP32 keeps the control logic simple, avoiding the cost and implementation requirements that complex control techniques may add. The tendon-driven mechanism with 3D-printed components and a wearable glove is intended to provide a low-cost and portable system, and the RehabEase application supports regular rehabilitation exercises and progress tracking. These benefits follow from the design, and their extent depends on the outcome of the prototype evaluation.

Limitations and Future Work

Threshold-based detection is simple, but it remains sensitive to the EMG signal noise, variations in muscle activity, and electrode placement noted in the introduction; therefore, the threshold may need to be re-determined for different users and sessions. Two-channel sensing also provides less information than the multi-channel and high-density sensor arrays used in some reviewed studies, and the system does not include fatigue estimation or adaptive assistance. The current evaluation covers prototype-level testing of EMG signals, movement detection, servo response, and finger-movement trials.

Future work will (i) improve signal reliability, movement accuracy, response time, and user comfort; (ii) evaluate the glove through more extensive trials, including supervised trials with patients; and (iii) investigate adaptive and learning-based intention detection and fatigue-aware control, as explored in several of the studies reviewed in this paper.

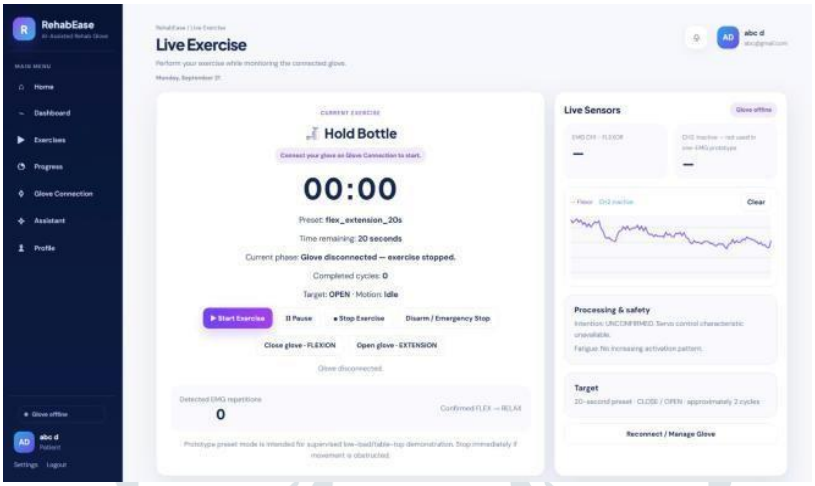
VIII. Final Conclusion

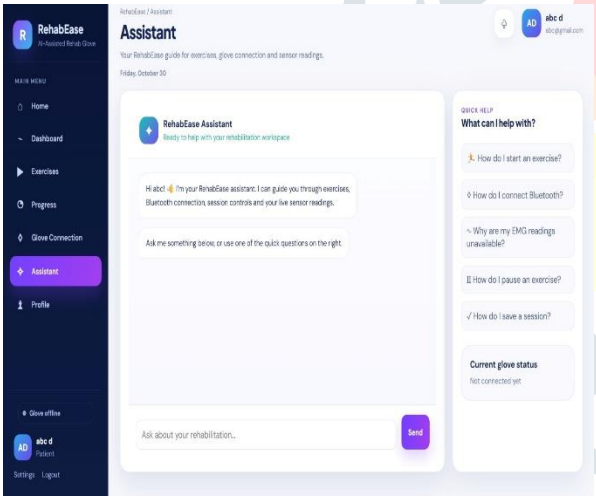
This project presents the design and implementation of an EMG-controlled robotic glove for hand rehabilitation. The system uses surface EMG signals to detect muscle activity and uses the detected movement intention to control five servo motors through a tendon-driven mechanism for assisted finger movement. The ESP32 provides the main control and processing platform, whereas the wearable glove and 3D-printed components provide the mechanical support required for finger actuation.

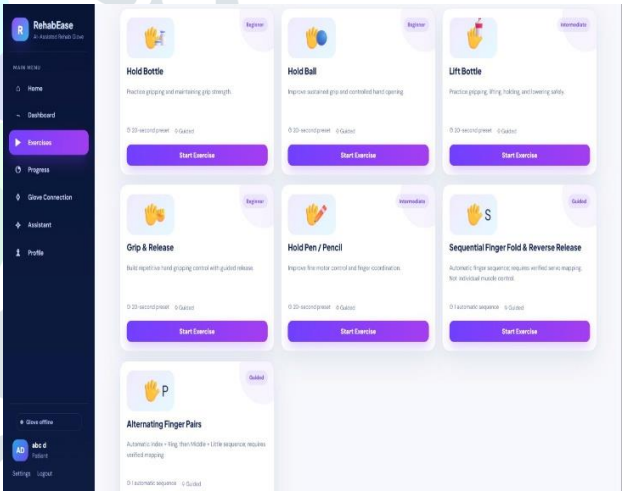
Through the development process, this project demonstrates how EMG sensing, embedded control, servo actuation, and mechanical design can be integrated into a single rehabilitation system. The implementation and testing of individual components provide a foundation for further improvement in signal reliability, movement accuracy, response time, and user comfort.

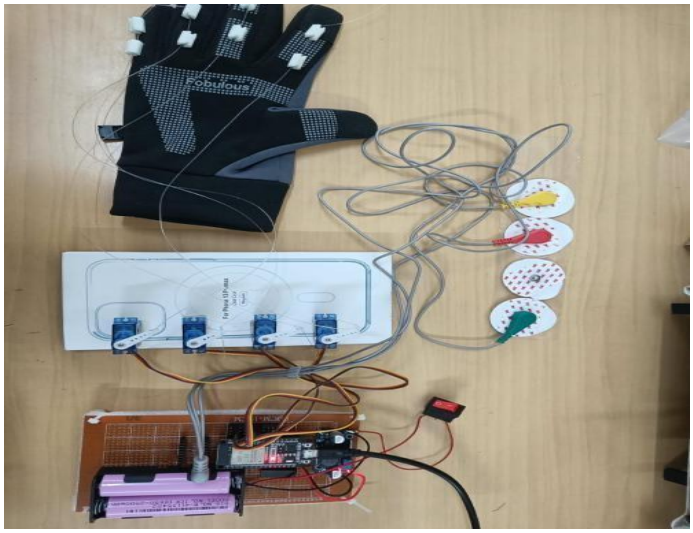
The proposed system provides a low-cost, portable, and user-controlled approach to hand rehabilitation, with the RehabEase application providing additional support for rehabilitation exercises and tracking progress. Further development and testing can improve the adaptability and reliability of the system for practical rehabilitation applications.

IX. RESULT









ACKNOWLEDGEMENT

The authors thank Dr. Dilip Kumar K, Principal/Director, and Dr. P. N. Sudha, Dean Academics and Head of the Department of Electronics and Communication Engineering, K. S. Institute of Technology, Bengaluru, for their encouragement, and the project coordinators, Dr. Rekha N and Mrs. Suma Santosh, for their coordination and support.

REFERENCES

[1] X. Wang, Y. Fang, Z. Zhang, X. Zhao, D. Xiong, and J. Li, "Review of Soft Robotic Gloves and Functional Electrical Stimulation Affecting Hand Function Rehabilitation for Stroke Patients," Biomimetics, vol. 11, no. 2, p. 104, 2026.

[2] R. Chen et al., "A Dual-Action Fabric-Based Soft Robotic Glove for Ergonomic Hand Rehabilitation," arXiv preprint arXiv:2604.00768, 2026.

[3] R. Ho and J. Zhang, "ReGlove: A Soft Pneumatic Glove for Activities of Daily Living Assistance via Wrist-Mounted Vision," arXiv preprint arXiv:2512.11824*, 2026.

[4] I. B. Abdallah, Y. Bouteraa, and A. Alotaibi, "A hybrid EMG-EEG interface for robust intention detection and fatigue-adaptive control of an elbow rehabilitation robot," Scientific Reports, vol. 15, no. 1,
p. 40895, 2025.

[5] C. Sun, X. Wang, L. Teng, Z. Zhang, and C. Y. Tang, "Assist-as-needed control with a soft robotic glove based on human-object contact estimation", Complex & Intelligent Systems, vol. 10, no. 2,
pp. 1917–1926, 2024.

[6] R. Ismail et al., "Design and testing of fabric-based portable soft exoskeleton glove for hand grasping assistance in daily activity," HardwareX, vol. 18, p. e00537, 2024.

[7] L. T. Gaeta, M. D. Albayrak, L. Kinnicutt, H. Schlegel, T. D. Ellis, and T. Ranzani, "A magnetically controlled soft robotic glove for hand rehabilitation," Device, vol. 2, no. 9, p. 100512, 2024.

[8] C. Suulker et al., "A User Study Method on Healthy Participants for Assessing an Assistive Wearable Robot Utilising EMG Sensing," arXiv preprint arXiv:2408.00048, 2024.

[9] D. Y. L. Lim, H. S. Lai, and R. C. H. Yeow, "A bidirectional fabric-based soft robotic glove for hand function assistance in patients with chronic stroke," Journal of NeuroEngineering and Rehabilitation, vol. 20, no. 1, p. 120, 2023.

[10] D. Bonilla et al., "Progressive Rehabilitation Based on EMG Gesture Classification and an MPC-Driven Exoskeleton," Bioengineering, vol. 10, no. 7, p. 770, 2023.

[11] S. Yang et al., "A low-cost and portable wrist exoskeleton using EEG-SEMG combined strategy for prolonged active rehabilitation," Frontiers in Neurorobotics, vol. 17, p. 1161187, 2023.

[12] R. A. R. C. Gopura, T. D. Lalitharatne, and D. Zhang, "Editorial: EMG/EEG signals-based control of assistive and rehabilitation robots, volume II," Frontiers in Neurorobotics, vol. 17, p. 1259773, 2023.

[13] D. Copaci, J. Arias, M. Gómez-Tomé, L. Moreno, and D. Blanco, "SEMG-Based Gesture Classifier for a Rehabilitation Glove," Frontiers in Neurorobotics, vol. 16, p. 750482, 2022.

[14] M. Sierotowicz et al., "EMG-driven Machine Learning Control of a Soft Glove for Grasping Assistance and Rehabilitation," IEEE Robotics and Automation Letters, vol. 7, no. 2, pp. 3173–3180, 2022.

[15] H. Zhou et al., "Toward Hand Pattern Recognition in Assistive and Rehabilitation Robotics Using EMG and Kinematics," Frontiers in Neurorobotics, vol. 15, p. 659876, 2021.

[16] Y. S. Ahmed, A. Q. Al-Neami, and S. Lateef, "Robotic Glove for Rehabilitation," Iraqi Journal for Electrical and Electronic Engineering, vol. 16, no. 1, pp. 91–101, 2020.

[17] Y. M. Zhou et al., "Soft Robotic Glove with Integrated Sensing for Intuitive Grasping Assistance Post Spinal Cord Injury," in Proc. IEEE Int. Conf. Robot. Autom. (ICRA), pp. 8059–8065, 2019.

[18] A. Moin et al., "An EMG Gesture Recognition System with Flexible High-Density Sensors and Brain-Inspired High-Dimensional Classifier," arXiv preprint arXiv:1802.10237, 2018.

[19] L. Cappello et al., "Assisting hand function after spinal cord injury with a fabric-based soft robotic glove," Journal of NeuroEngineering and Rehabilitation, vol. 15, no. 1, p. 91, 2018.

[20] P. Polygerinos, K. C. Galloway, S. Sanan, M. Herman, and C. J. Walsh, "EMG Controlled Soft Robotic Glove for Assistance During Activities of Daily Living," in Proc. IEEE Int. Conf. Robot. Autom. (ICRA), pp. 55–60, 2015.