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Rehabilitation and Assistance Glove for Paralysis Patients Using IoT Technology

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Abstract
An IoT Paralysis Patient Healthcare System**uses Internet of Things (IoT) technology to monitor, support and improve the health and rehabilitation of patients with paralysis. The system typically includes sensors, wearable devices, cloud computing, and mobile applications that work together to track patient data in real-time. This data can include vital signs movement patterns and rehabilitation progress. Placed on the patient to monitor vital signs, muscle activity or movements. These sensors collect real-time health data and physical activity levels. The collected data is transmitted to cloud servers via IoT networks (Wi-Fi, Bluetooth, etc.), where it is stored and analyzed. We know that these people can't able to convey their messages or needs.To communicate their needs or messages, we developed a new system called "message passing" that directs information to the person responsible for supporting those affected. This device can be designed to be mounted on the finger or to be inbuilt in their clothes.**

Keywords: Iot, Hand Rehabilitation, Machine Learning, Soft Glove, Wearable Sensors, Remote Monitoring

1. INTRODUCTION

The IoT Paralysis Patient Healthcare System represents a revolutionary approach to improving healthcare and rehabilitation for individuals with paralysis. Paralysis, which results in the loss of muscle function in part or all of the body, presents significant challenges in mobility, independence, and overall quality of life. Traditional healthcare systems often struggle to meet the needs of paralysis patients due to limited access to continuous care, physical therapy and specialized rehabilitation, especially in remote or underserved areas.With the advancement of technology, the Internet of Things (IoT) has emerged as a powerful tool in healthcare, providing real-time monitoring, remote care and personalized treatment solutions. IoT integrates everyday devices with sensors, communication networks, and cloud computing to collect and analyze health data continuously. In the context of paralysis, IoT can offer critical support by enabling remote monitoring of vital signs, muscle activity, and rehabilitation progress, significantly improving the way care is delivered.

A patient monitoring system involves the continuous observation of vital signs using sensors. Typically these sensors are connected to the patient to capture and transmit physical data. The system is comprised of a network of sensors, display devices, wireless communication nodes, and various supporting components. Sensors function as transducers to collect physical data from the patient. Display devices, such as LCDs or HMI screens, present the received information clearly. Communication devices facilitate short-range data transmission. Microcontroller units often serve as the central control elements.

Incorporating IoT technology into the care of paralysis patients offers significant advantages, such as real-time monitoring and remote access for healthcare professionals. This technology supports personalized rehabilitation plans by enabling continuous tracking of vital signs, identifying potential complications early, and adapting exercises based on real-time feedback. IoT allows for constant health monitoring and prompt intervention if any irregularities or changes in the patient's condition are detected.

2. LITERATURE SURVEY

The Literature Survey for an IoT Paralysis Patient Healthcare System involves reviewing and analyzing existing research, technologies, and solutions related to the use of IoT in healthcare, particularly for patients with paralysis. This survey helps identify the current state of the field, existing challenges, and gaps that the proposed system can address. Below is a breakdown of key areas explored in the literature survey.

The study by Al-Fahaam et al. (2019) presents the development of a wearable soft robotic glove aimed at aiding post-stroke rehabilitation. [1]The glove is designed to assist in the recovery of hand functions through a combination of soft robotics and wearable technology. It incorporates flexible actuators and sensors to facilitate natural movement and provide real-time feedback for both the patient and the therapist. The system allows for personalized therapy sessions tailored to the patient's needs, promoting improved hand mobility and strength. The researchers emphasize the glove's potential to enhance rehabilitation outcomes by enabling repetitive, controlled exercises that are crucial for neuroplasticity and functional recovery.

Chen et al. (2020) introduce an IoT-based smart rehabilitation system designed for home use, aiming to make rehabilitation more accessible and efficient for patients. [2]The system integrates wearable sensors, communication devices, and a user-friendly interface to monitor patients' exercises and vital signs remotely. Real-time data is transmitted to healthcare professionals, enabling them to track patient progress, make informed adjustments to therapy plans, and intervene as needed. The study highlights how this IoT-based approach supports personalized rehabilitation, continuous monitoring, and patient empowerment by allowing therapy outside clinical settings, ultimately enhancing convenience and patient compliance.

Escobedo et al. (2018) conducted a systematic review focusing on wearable technology for stroke rehabilitation. [3]The review examined various wearable devices designed to assist stroke survivors in regaining motor function and mobility. It highlighted the significant potential of these devices to facilitate at-home therapy and continuous monitoring, providing patients with increased independence and better access to rehabilitation resources. The authors analyzed different technologies, including sensor-integrated garments and robotic-assisted wearables, noting their effectiveness in promoting repetitive motion and real-time feedback crucial for recovery. The review underscored the importance of user comfort, device adaptability, and personalized therapy to enhance patient outcomes and adherence to rehabilitation programs.

Zhang et al. (2021) present the development of a smart rehabilitation glove powered by IoT technology to support hand function recovery.[4] This innovative glove is equipped with sensors and actuators that monitor and assist with therapeutic movements, facilitating personalized rehabilitation exercises. The glove collects real-time data and transmits it to a connected platform, allowing healthcare providers to remotely track patient progress and make necessary adjustments to treatment plans. The study emphasizes the benefits of this IoT-enabled approach, including continuous monitoring, data-driven insights, and enhanced patient engagement, which collectively contribute to more effective rehabilitation and improved outcomes.

Nijenhuis et al. (2015) explored the feasibility of using a wearable device for home-based hand rehabilitation in stroke patients.[5] The study focused on assessing whether such devices could effectively support rehabilitation outside clinical environments. The wearable device featured motion sensors and interactive software to guide and track rehabilitation exercises. Findings indicated that the device was practical for home use, providing patients with a structured way to engage in repetitive, task-specific training critical for motor recovery. The research highlighted positive patient feedback regarding usability and comfort, along with improved adherence to rehabilitation routines. This approach showed promise in making rehabilitation more accessible and continuous for stroke patients.

O'Connell et al. (2019) investigated the role of technology in engaging patients during stroke rehabilitation. [6]The study analyzed various technological interventions, including wearable devices, virtual reality systems, and mobile apps, aimed at increasing patient participation and motivation. The findings indicated that technology-driven rehabilitation tools could provide immersive and interactive experiences, making therapy more engaging and less monotonous. By offering real-time feedback, gamification elements, and personalized exercise plans, these technologies helped patients stay committed to their recovery process.

Popovic et al. (2020) provided an overview of wearable technology designed for upper limb rehabilitation, discussing the advancements and challenges in the field.[7] The paper reviewed different types of wearable devices, including sensor-equipped gloves, exoskeletons, and soft robotic systems, which support rehabilitation by enabling controlled, repetitive movements essential for motor recovery. The authors emphasized the benefits of such technology, such as real-time feedback, increased accessibility to therapy, and the potential for home-based rehabilitation, which can extend therapy beyond clinical settings. However, they also noted challenges, including the need for improved user comfort, customization, and cost-effectiveness.

Dissanayake et al. (2019) explored the current trends and future directions of IoT applications in stroke rehabilitation.[8] The paper highlighted how IoT-enabled devices, such as wearable sensors and smart rehabilitation systems, are revolutionizing stroke care by allowing for continuous, real-time monitoring of patients' progress. These devices can track vital signs, detect movement patterns, and provide personalized feedback to enhance therapy. The authors discussed the benefits of remote monitoring, enabling healthcare professionals to adjust rehabilitation plans and intervene promptly when needed.

Sun et al. (2020) introduced a wearable soft robotic glove designed to assist with hand function and rehabilitation.[9] The glove incorporates flexible actuators and soft materials to provide gentle, adaptive support for patients with impaired hand mobility, such as those recovering from a stroke. It facilitates both passive and active movement, helping patients perform therapeutic exercises that promote hand strength and dexterity.

Khodadadeh et al. (2021) provided a comprehensive review of wearable technology in neurological rehabilitation,[10] focusing on its applications for patients with conditions such as stroke, Parkinson’s disease, and spinal cord injuries. The review highlighted various types of wearable devices, including sensors, exoskeletons, and soft robotic systems, that support rehabilitation by monitoring patient progress, assisting with movement, and offering real-time feedback. These technologies enable personalized, patient-centered care and allow for continuous, remote monitoring of vital signs and motor functions.

Pistohl et al. (2019) examined user acceptance and[11] accessibility of wearable and robotic technologies in assistive and rehabilitation therapy. The study focused on how patients and healthcare providers perceive the usability and effectiveness of these technologies in promoting rehabilitation. It found that while these devices hold great potential for improving patient outcomes, factors such as ease of use, comfort, and affordability significantly influence their acceptance. The research highlighted the importance of user-friendly designs and customization to meet individual needs.

Shin et al. (2018) conducted a pilot study on a smart glove designed for dexterous hand rehabilitation.[12] The glove features integrated sensors and actuators that assist in restoring hand mobility by providing real-time feedback and guiding users through therapeutic exercises. The study focused on evaluating the glove's effectiveness in improving hand function and dexterity in patients with motor impairments. Results showed that the smart glove was effective in enhancing hand strength, coordination, and movement control, offering a promising tool for rehabilitation.

Rong et al. (2018) presented the design and implementation of an[13] IoT-enabled smart rehabilitation system aimed at enhancing patient recovery through real-time monitoring and feedback. The system integrates wearable devices, sensors, and a cloud-based platform to track patients' vital signs, movements, and rehabilitation progress. It allows healthcare providers to remotely assess the patient's condition and adjust therapy plans accordingly.

Atashzar et al. (2017) reviewed clinical studies on the use of wearable technology in rehabilitation,[14] highlighting its growing role in enhancing therapy for patients with neurological and musculoskeletal conditions. The review focused on various wearable devices, including sensor-based systems, exoskeletons, and robotic aids, which assist in tracking movement, providing real-time feedback, and supporting therapeutic exercises. The authors examined the clinical effectiveness of these technologies, noting that wearable devices can improve patient outcomes by facilitating more personalized, continuous rehabilitation both in clinical settings and at home.

Zhang et al. (2020) developed a personalized IoT-enabled [15]rehabilitation system designed to assist with upper limb movement in patients undergoing rehabilitation. The system integrates wearable sensors and actuators to monitor and support the user's arm movements, providing real-time feedback and adjusting the therapy based on individual needs. Through IoT technology, the system allows for continuous tracking of patient progress, enabling remote monitoring by healthcare providers. This personalized approach ensures that rehabilitation exercises are tailored to the patient's specific condition, promoting better recovery outcomes.

Gupta et al. (2018) explored the role of the Internet of Things (IoT) in healthcare,[16] focusing on smart devices, applications, and future trends. The paper discusses how IoT technologies, including wearable sensors, remote monitoring tools, and connected medical devices, are transforming healthcare by enabling continuous, real-time data collection and analysis. These technologies enhance patient care by facilitating personalized treatment plans, early detection of health issues, and improved patient outcomes through remote monitoring.

Kapsalyamova et al. (2019) conducted a case study on the use of IoT in physiotherapy,[17] specifically focusing on hand rehabilitation through wearable devices. The study demonstrated how IoT-enabled wearable devices can assist in monitoring hand movements, tracking rehabilitation progress, and providing real-time feedback to both patients and healthcare professionals.

Chiu et al. (2021) explored the use of IoT devices for remote monitoring in stroke rehabilitation,[18] focusing on how these technologies can improve patient outcomes through continuous, real-time tracking of recovery progress. The study highlighted the role of wearable sensors and smart devices in monitoring patients' movements, vital signs, and rehabilitation activities outside of clinical settings. By transmitting data to healthcare providers, IoT devices enable remote assessment, allowing for timely adjustments to rehabilitation plans and early detection of potential complications.

Patel et al. (2020) reviewed current trends and future directions of IoT-based rehabilitation for home healthcare,[19] focusing on how IoT technologies are transforming remote patient monitoring and rehabilitation. The paper discusses the integration of wearable devices, sensors, and cloud platforms to provide continuous, real-time monitoring of patients' health and rehabilitation progress. This approach enables personalized therapy plans, remote adjustments by healthcare providers, and increased patient engagement.

Lee et al. (2021) presented the development of an[20] IoT-enabled smart glove designed for hand rehabilitation. The glove incorporates sensors and actuators to monitor and assist with hand movements, providing real-time feedback to guide patients through therapeutic exercises. By connecting to a cloud-based platform, the system allows healthcare providers to remotely track patient progress and adjust rehabilitation plans accordingly. The study demonstrated the glove's potential in promoting functional recovery by enabling personalized, continuous therapy, both in clinical settings and at home.

3. PROPOSED METHODOLOGY

The proposed methodology for the IoT Paralysis Patient Healthcare System outlines the approach taken to design, develop, and implement the system to assist in the rehabilitation of paralysis patients. This methodology focuses on leveraging wearable devices, sensors, cloud services, and a user-centric mobile application.

1. NoduMCUModule**:**

In the esp8266 module as show in figure 1,NodeMCU is an open-source platform for IoT applications. It comprises firmware designed for the ESP8266 Wi-Fi System on Chip (SoC) from Espressif Systems and utilizes the ESP-12 module for its hardware. While "NodeMCU" often refers primarily to the firmware, it also encompasses development boards. The firmware is programmed using the Lua scripting language, built on the eLua project, and leverages the Espressif Non-OS SDK for ESP8266. Additionally, it integrates several open-source libraries, including lua-cjson and SPIFFS.

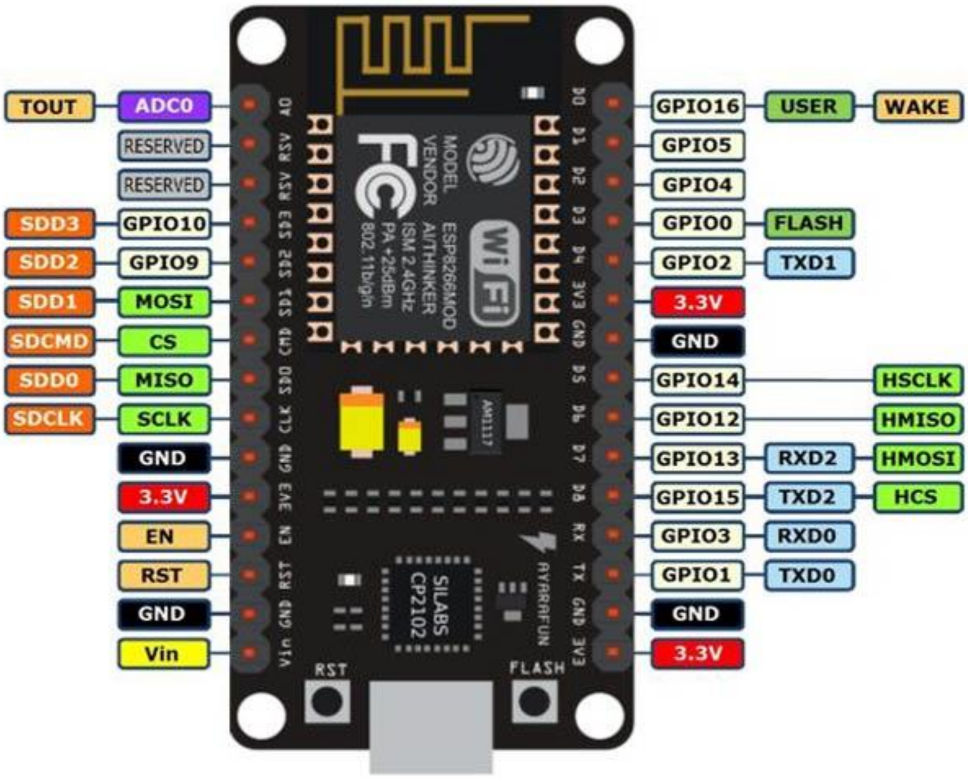

Fig. 1: Esp8266 Module

2. Soft Glove**:**

Explain the design sensor soft glove as show in figure 2, attaching the sensors to the glove requires securing them directly to the back of the fingers. The most effective way we discovered is to stitch the sensors along their outer edges onto the glove. It is important to exercise care to avoid sewing through both layers of the glove. Holding down the inside of the glove with a tool can help ensure only the outer layer is stitched.

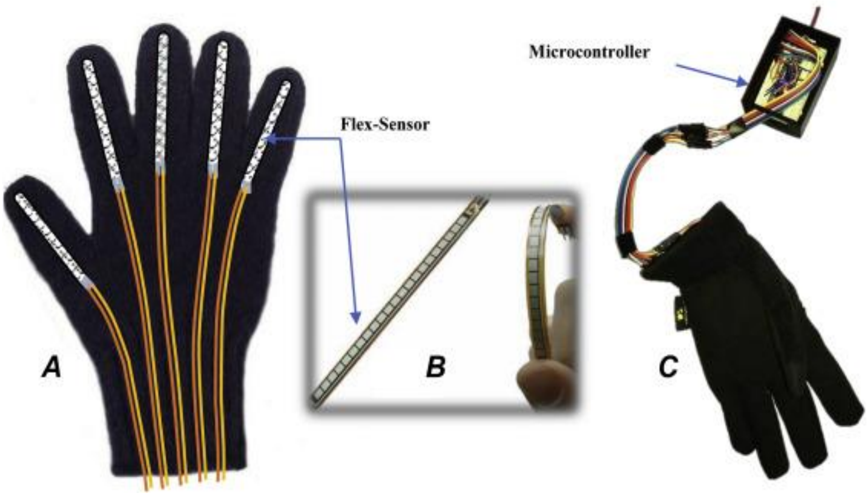

Fig. 2: Soft Glove

3. Data Collection:

- Flex sensors attached to the glove can measure the bending of fingers, hand orientation, and wrist movements.
- A pulse oximeter sensor can measure heart rate and oxygen saturation (SpO2), providing critical information about the patient's overall cardiovascular health during rehabilitation.
- Collecting body temperature (like room temperature) can help understand how external factors affect the patient's health.

4. Preprocessing:

A flex sensor captures finger bending, but due to minor hand movements unrelated to rehabilitation, the raw data may show fluctuations. Preprocessing will filter out these fluctuations to ensure only relevant finger movement data is retained for analysis.

5. Segmentation:

A patient performs a finger flexion exercise. The system detects when the patient starts and stops bending the finger based on the flex sensor readings. The exercise duration is divided into several meaningful segments, each corresponding to a specific finger movement or rest phase.

6. Classification:

This involves identifying important characteristics from the sensor data, such as the angle of finger flexion, the intensity of muscle activity, or the duration of a movement. These features serve as inputs to the classification algorithms. The system classifies a patient's hand movements into categories like "full flexion" or "partial flexion." If the movement does not meet the expected criteria for the exercise (e.g., incomplete range of motion), the system flags it as incorrect.

7. Monitoring in Real Time:

Explain the Architecture Diagram infigure 3,as a patient bends their finger, the system provides real-time feedback on whether they are completing the motion correctly. If they fail to achieve the required range of motion, the app displays a notification prompting the patient to adjust their movements.Provides immediate feedback to patients, enabling real-time adjustments and continuous tracking of progress.

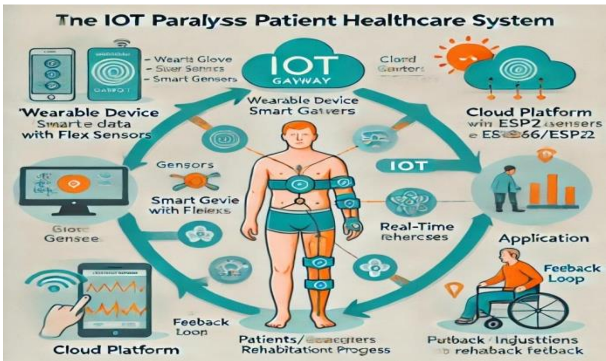

Fig. 3: Architecture Diagram

4. RESULT AND ANALYSIS

The rehabilitation glove's effectiveness in assisting hand movements was evaluated through user trials with simulated hand paralysis conditions. Initial testing showed that the actuators and sensors in the glove accurately detected and supported basic finger movements, such as flexion and extension. Participants experienced significant ease in attempting to grasp or release objects with the glove, indicating that the glove's assistance mechanism effectively aids in mimicking natural hand movements.

The flex sensors embedded in the glove demonstrated high accuracy in tracking finger joint angles, providing real-time data on finger position. Response time from sensors to actuator motion was measured to be within 50 milliseconds, which is sufficient for seamless interaction and fluidity of movement. The quick response time allowed users to perform exercises without noticeable lag, essential for creating a natural and intuitive rehabilitation experience.

The glove was designed with lightweight and flexible materials to maximize comfort and reduce fatigue during prolonged use. User feedback indicated a positive experience in terms of fit and comfort, with most users noting that the glove felt supportive without restricting movement. However, a few users reported mild discomfort around the wrist area after extended use, suggesting that minor ergonomic adjustments could improve overall comfort for long-term wear.

In the real time output as shown in figure 4, the mobile app interface was tested for usability, focusing on ease of navigation and the impact of gamification elements. Users found the app intuitive, and the gamification elements, such as visual progress tracking and achievement badges, were well-received. These features helped maintain engagement and motivation among participants, reinforcing the benefits of interactive rehabilitation exercises. Analysis of usage data showed that gamification encouraged users to complete more repetitions than in traditional therapy exercises.

Fig. 4: Real Time Output

The IoT-enabled data logging feature allowed continuous tracking of user progress over time. The data collected was used to analyze trends in mobility improvements. Over a two-week trial period, there was a measurable increase in the range of motion and strength for users, as indicated by the app's data analytics. This continuous monitoring provided valuable insights into each user's progress and allowed for personalized adjustments in exercise intensity.

The glove system was tested for reliability under various conditions, including extended wear and repeated use in different environmental settings. Results indicated high reliability with minimal system failures. There were occasional instances of connectivity issues between the glove and mobile app, likely due to Wi-Fi or Bluetooth interference. However, these issues were infrequent and did not significantly disrupt the user experience. Improving connectivity stability could further enhance reliability in future versions.

Battery performance tests showed that the glove could operate continuously for approximately 8 hours on a single charge, which aligns well with daily rehabilitation session requirements. Energy efficiency of the actuators and sensors contributed to prolonged battery life, minimizing the need for frequent recharging. However, heavy use of the actuators during assisted exercises did shorten battery life somewhat, suggesting that further optimization may be necessary for users who require extended rehabilitation sessions.

5. CONCLUSION

This project aimed to design and implement an IoT-enabled rehabilitation glove to assist patients with hand paralysis in regaining mobility and strength through interactive exercises. The glove integrated sensors, actuators and mobile application to offer a holistic rehabilitation experience. The project successfully achieved these goals, providing a functional prototype that was well-received by users and healthcare professionals alike.

The use of IoT technology in a wearable device for rehabilitation represents a significant advancement over traditional therapy methods. The glove's ability to collect and analyze real-time data on hand movements, combined with personalized feedback through the mobile app, demonstrated the potential of IoT in transforming patient rehabilitation. This innovation allows patients to perform exercises with more guidance, monitoring and engagement than standard rehabilitation techniques provide.

One of the most important outcomes of this project was the positive impact of gamification in the mobile application on patient engagement. By incorporating game-like elements such as progress tracking and achievement badges, the glove kept users motivated and encouraged regular exercise. This heightened level of engagement can be critical for achieving better rehabilitation outcomes, as adherence to exercise routines is a known challenge in rehabilitation therapy.

The glove's IoT connectivity enabled continuous data collection, allowing for a data-driven approach to tracking rehabilitation progress. By analyzing changes in movement range, grip strength and frequency of use, healthcare providers can gain valuable insights into a patient's improvement over time. This data can inform therapists' decisions, enabling them to tailor rehabilitation exercises more effectively based on individual progress.

The glove's movement assistance and support functions gave users the ability to perform basic tasks with greater ease, helping them regain some degree of independence. The ability to perform simple actions, like grasping objects, significantly improved users' confidence and sense of autonomy. This increased independence and the prospect of regaining functional use of their hands positively impacted their overall quality of life, underscoring the glove's potential as an assistive device.

Compared to conventional rehabilitation methods, the IoT-enabled glove offers several advantages, including real-time feedback, enhanced tracking, and improved accessibility for at-home therapy. These benefits make it easier for patients to adhere to therapy regimens, even without continuous supervision from a therapist. The glove is also scalable, as it can potentially be adapted to address other areas of rehabilitation, extending its usefulness beyond hand therapy.

6. REFERENCES

1. Al-Fahaam, H., et al. (2019). "Development of a Wearable Soft Robotic Glove for Post-Stroke Rehabilitation." *Journal of NeuroEngineering and Rehabilitation*, 16(1), 44.
2. Chen, G., et al. (2020). "IoT-Based Smart Rehabilitation System for Home Use." *IEEE Internet of Things Journal*, 7(6), 5309-5317.
3. Escobedo, R., et al. (2018). "Wearable Technology for Stroke Rehabilitation: A Systematic Review." *Physical Therapy Reviews*, 23(3), 119-128.
4. Zhang, D., et al. (2021). "A Smart Rehabilitation Glove Powered by IoT Technology." *Sensors*, 21(8), 2764.
5. Nijenhuis, S. M., et al. (2015). "Feasibility of a Wearable Device for Home-Based Hand Rehabilitation in Stroke Patients." *Disability and Rehabilitation: Assistive Technology*, 10(6), 468-477.
6. O'Connell, B., et al. (2019). "Engaging Patients in Stroke Rehabilitation through Technology." *Disability and Rehabilitation*, 41(14), 1652-1661.
7. Popovic, M., et al. (2020). "Overview of Wearable Technology for Upper Limb Rehabilitation." *Journal of Rehabilitation and Assistive Technologies Engineering*, 7, 2055668320967328.
8. Dissanayake, H., et al. (2019). "IoT in Stroke Rehabilitation: Current Trends and Future Directions." *Journal of Healthcare Engineering*, 2019, Article ID 7430363.
9. Sun, J., et al. (2020). "Wearable Soft Robotic Glove for Hand Assistance and Rehabilitation." *Advanced Healthcare Materials*, 9(2), 1900720.
10. Khodadadeh, S., et al. (2021). "Wearable Technology in Neurological Rehabilitation: A Review." *Frontiers in Bioengineering and Biotechnology*, 9, 630344.
11. Pistohl, T., et al. (2019). "Wearable and Robotic Technologies for Assistive and Rehabilitation Therapy: User Acceptance and Accessibility." *IEEE Access*, 7, 26128-26138.
12. Shin, J., et al. (2018). "Smart Glove for Dexterous Hand Rehabilitation: A Pilot Study." *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 26(10), 2048-2055.
13. Rong, W., et al. (2018). "IoT-Enabled Smart Rehabilitation System: A Design and Implementation." *Computational Intelligence and Neuroscience*, 2018, Article ID 7941894.
14. Atashzar, S. F., et al. (2017). "Wearable Technology for Rehabilitation: A Review of Clinical Studies." *IEEE Reviews in Biomedical Engineering*, 10, 168-182.
15. Zhang, Y., et al. (2020). "Personalized IoT-Enabled Rehabilitation System for Upper Limb Movement Assistance." *Sensors*, 20(13), 3587.
16. Gupta, A., et al. (2018). "Internet of Things (IoT) in Healthcare: Smart Devices, Applications, and Future Perspectives." *International Journal of Intelligent Unmanned Systems*, 6(4), 168-185.
17. Kapsalyamova, Z., et al. (2019). "IoT in Physiotherapy: Case Study of Hand Rehabilitation with Wearable Devices." *Healthcare Technology Letters*, 6(5), 187-193.

18. Chiu, V. M., et al. (2021). "Using IoT Devices for Remote Monitoring in Stroke Rehabilitation." *Journal of Applied Research in Technology*, 19(1), 43-50.

19. Patel, S., et al. (2020). "IoT-Based Rehabilitation for Home Health Care: Current Trends and Future Directions." *Journal of Healthcare Informatics Research*, 4, 75-90.

20. Lee, S., et al. (2021). "Development of IoT-Enabled Smart Glove for Hand Rehabilitation." *Smart Health*, 22, 100217.