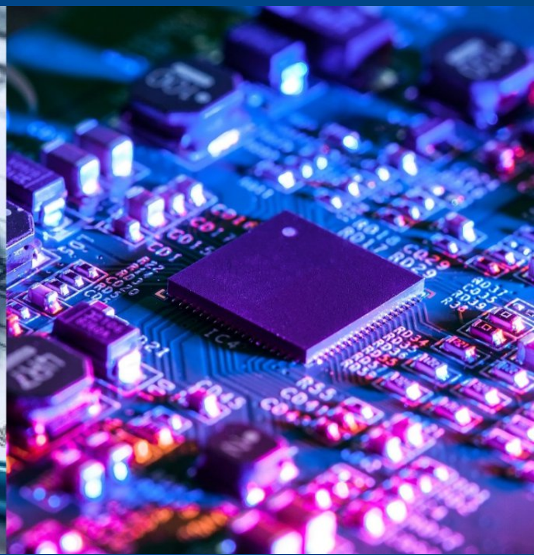
ISSN: 2582-7219

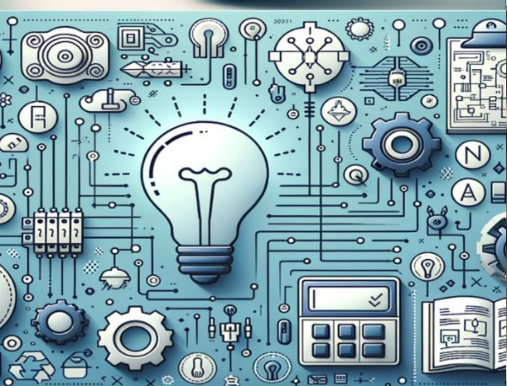




International Journal of Multidisciplinary Research in Science, Engineering and Technology

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.206

Volume 9, Issue 4, April 2026

www.ijmrset.com ijmrset@gmail.com +91 6381 907 438 +91 63819 07438

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

IoT-Based Muscle Fatigue Detection for Stroke Rehabilitation

Naresh Kumar K, Angel B, Shreevidhya P, Thrisha D

Assistant Professor, Department of BME, GRT-IET, Tiruttani, Tamil Nadu, India

BME IV-Year Student, Department of BME, GRT-IET, Tiruttani, Tamil Nadu, India

BME IV-Year Student, Department of BME, GRT-IET, Tiruttani, Tamil Nadu, India

BME IV-Year Student, Department of BME, GRT-IET, Tiruttani, Tamil Nadu, India

ABSTRACT: Stroke survivors often experience muscle fatigue that impedes rehabilitation progress and increases the risk of injury. Traditional rehabilitation settings may not effectively monitor subtle fatigue-induced compensatory movements, particularly in home-based environments. This study introduces an Internet of Things (IoT)-enabled system designed to detect muscle fatigue in real-time during stroke rehabilitation exercises. The system integrates wearable sensors, such as strain gauges and surface electromyography (sEMG), to continuously monitor muscle activity and joint movements. Data collected by these sensors are wirelessly transmitted to a central processing unit, where advanced algorithms analyze the signals to identify signs of fatigue-induced compensatory actions. The system provides immediate feedback to both patients and healthcare providers, enabling timely adjustments to rehabilitation protocols. By facilitating early detection of muscle fatigue, this IoT-based approach aims to enhance the effectiveness of stroke rehabilitation, reduce the risk of injury, and promote more personalized and adaptive therapy plans.

KEYWORDS: Wearable sensors, Surface electromyography (sEMG), Strain sensors, Real-time monitoring, Adaptive therapy, Remote patient monitoring.

I. INTRODUCTION

Stroke often leads to muscle weakness, reduced endurance, and fatigue, especially in the upper limbs. Rehabilitation exercises are essential to recover motor function, but fatigue can limit the amount and effectiveness of training, risking slower recovery or even injury.

IoT-based systems combine wearable sensors (e.g. surface electromyography or sEMG, inertial sensors), wireless communication, and data processing (often via machine learning) to monitor muscle activity in real time. By detecting signs of fatigue, these systems can adapt therapy (for example, by reducing load or increasing rest), provide feedback, or alert therapists to adjust sessions. Recent work shows that integrating such fatigue detection into rehabilitation robotics or wearable devices can prolong effective training, improve patient engagement, and potentially improve outcomes.

For example, remote wrist-forearm rehabilitation systems using IoT and SVM classifiers detect fatigue from EMG signals, enabling adaptive protocols that combine robot-generated and patient-generated torque.

II METHODOLOGY

1.Surface Electromyography (sEMG)

- Surface Electromyography (sEMG) is a widely used, non-invasive technique for monitoring muscle activity, especially in medical and rehabilitation applications such as stroke recovery. It works by detecting the electrical signals generated when muscle fibers contract and relax. In this system, small electrodes are placed on the skin surface directly above the targeted muscle group. These electrodes pick up very weak electrical signals, typically in the range of microvolts, which represent the neuromuscular activity of the patient.

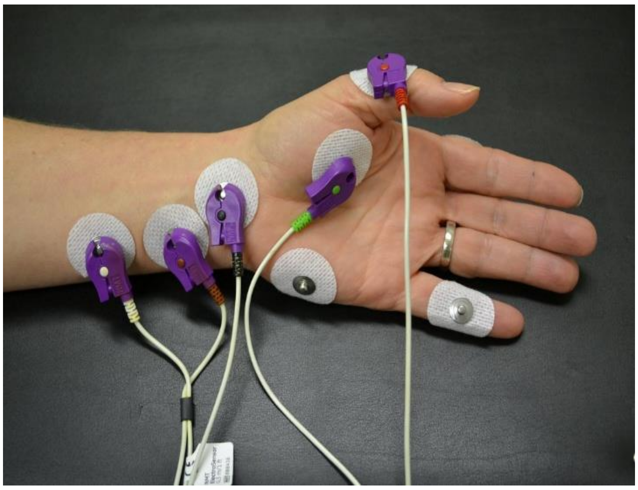
- Since the raw sEMG signals are extremely weak and prone to noise from external sources like power lines or body movement, they must first be amplified and filtered. This is done using an EMG bio-amplifier, which increases the signal strength while maintaining signal integrity. Additionally, filters such as low-pass, high-pass, and notch filters are applied to remove unwanted noise and interference, ensuring that only meaningful muscle activity data is retained.

-

After amplification and filtering, the analog sEMG signals are converted into digital form using the ADS1115 Analog-to-Digital Converter (ADC). The ADS1115 provides high-resolution (16-bit) conversion, which is important for accurately capturing subtle variations in muscle activity. The digitized data is then sent to the ESP32 microcontroller, which acts as the central processing unit of the system.

The ESP32 processes the incoming data in real time and analyzes key signal features such as amplitude and frequency. During muscle fatigue, the amplitude of the EMG signal generally increases due to the recruitment of more muscle fibers, while the frequency tends to decrease due to reduced conduction velocity in fatigued muscles. By continuously monitoring these parameters, the system can effectively detect the onset of muscle fatigue.

Once fatigue is detected, the system provides immediate feedback to the patient through output devices such as a buzzer, vibration motor, or display. This real-time feedback is crucial in rehabilitation, as it helps prevent overexertion, reduces the risk of further injury, and ensures that exercises are performed within safe limits. Overall, the integration of sEMG sensing, signal processing, and IoT-based feedback makes the system highly effective for improving patient engagement and enhancing the outcomes of stroke rehabilitation.



2.EMG bio -amplifier

once muscle fatigue is detected from the sEMG signal analysis, the system immediately reacts by providing feedback to the patient through different output components integrated into your hardware setup.

When the ESP32 identifies fatigue (based on increased amplitude and decreased frequency of the EMG signal), it sends signals to output devices such as a **buzzer**, **vibration motor (V919)**, or **OLED display**. The buzzer can give an audible alert to notify the patient to stop or slow down the exercise. At the same time, the vibration motor provides a tactile alert, which is especially useful if the patient cannot clearly hear or see the warning. The OLED display can show messages like “Fatigue Detected” or “Take Rest,” giving clear visual guidance.

This real-time feedback mechanism is very important in your project because stroke patients often have reduced muscle control and may not recognize when their muscles are overworked. By alerting them instantly, your system helps prevent overexertion, which could otherwise lead to muscle damage or delay recovery. It ensures that the rehabilitation exercises are performed within safe limits and with proper rest intervals.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

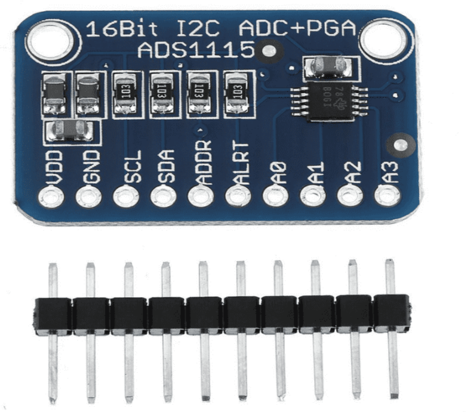
(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Additionally, since your project is IoT-based, the ESP32 can also transmit the fatigue data wirelessly to a mobile app or cloud platform. This allows doctors or caregivers to monitor the patient's progress remotely and adjust rehabilitation plans accordingly.

Overall, this feedback system makes your project more intelligent and patient-friendly. It not only enhances safety but also improves patient engagement by guiding them during exercises, ultimately leading to more effective and controlled stroke rehabilitation.

4. **ADS1115 ADC**

the ADS1115 ADC plays a crucial role in converting analog signals from sensors into accurate digital data for processing. It is a high-resolution 16-bit analog-to-digital converter, which allows it to capture very small and weak signals with high precision, making it ideal for applications like EMG and force sensing. In your project, the ADS1115 receives analog inputs from the EMG bio-amplifier, which measures muscle electrical activity, and the FSR 402 sensor, which detects grip force or pressure. These signals are often very weak and sensitive, so the high resolution of the ADS1115 ensures that even minor changes in muscle activity and force are accurately detected. The ADS1115 is connected to the ESP32 microcontroller using the I2C communication protocol through SDA and SCL pins, enabling efficient and simple data transfer. After converting the analog signals into digital values, it sends the data to the ESP32, where further analysis is performed to identify muscle activity patterns and detect fatigue. This accurate and reliable signal conversion significantly improves the overall performance of the system, ensuring effective monitoring and



5.) ESP32 (38-pin board

ESP32 (38-pin board) acts as the central controller and forms the core of the entire embedded system. It is a powerful microcontroller that integrates a processor, memory, and multiple input/output interfaces in a single compact chip, making it ideal for real-time biomedical applications. In your project, the ESP32 is responsible for collecting data from various sensors such as the EMG bio-amplifier (for muscle electrical activity), FSR 402 (for grip force), and MPU6050 (for motion and joint movement). These sensor signals, after being converted into digital form using the ADS1115 ADC, are sent to the ESP32 for processing.

The ESP32 then analyzes this data to detect muscle fatigue by evaluating parameters like signal amplitude, frequency changes, and force variations. Based on this analysis, it makes decisions and controls output devices such as the OLED display, buzzer, and vibration motor to provide real-time feedback to the patient. For example, when fatigue is detected,

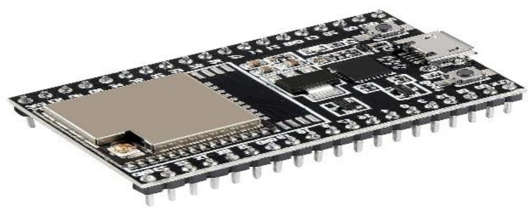
ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

it can trigger alerts to indicate that the patient should rest. Additionally, since the ESP32 has built-in Wi-Fi and Bluetooth capabilities, it enables IoT functionality by transmitting patient data to a mobile app or cloud platform for remote monitoring by doctors or caregivers.

All these components—sensors, ADC, ESP32, and output devices—work together as a single unit to perform the specific task of monitoring muscle fatigue. This integration forms an embedded system designed for continuous, real-time operation, ensuring accurate tracking, timely feedback, and improved rehabilitation outcomes for stroke patients**.**

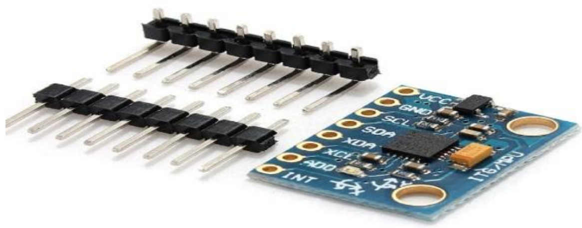


6.) MPU6050

MPU6050 sensor plays an important role in tracking the patient's movement and posture during exercises. It is a motion-tracking module that combines a 3-axis accelerometer and a 3-axis gyroscope in a single unit, making it compact and efficient for real-time applications. In your project, the accelerometer measures linear motion such as hand or arm acceleration, while the gyroscope measures rotational movements, helping to determine joint angles and orientation.

The MPU6050 continuously collects motion data while the patient performs rehabilitation exercises, allowing the system to analyze movement patterns and detect any abnormalities such as tremors, jerky motions, or improper posture. This is especially useful for stroke patients, as their movements may be unsteady or inconsistent. By identifying such irregularities, the system can ensure that exercises are performed correctly and safely.

The sensor communicates with the ESP32 microcontroller using the I2C protocol through SDA and SCL pins, enabling efficient and real-time data transfer. The ESP32 processes this motion data along with EMG and force sensor data to get a complete understanding of the patient's physical condition. This combined analysis improves the accuracy of muscle fatigue detection and provides better feedback to the user. Overall, the MPU6050 enhances your project by adding motion intelligence, making the rehabilitation monitoring system more effective, reliable, and responsive.



1.**Actuation System**

The actuation system consists of a buzzer and a vibrator (V919), which are used to provide immediate alerts when muscle fatigue is detected. These components act as output devices that respond to signals from the ESP32 microcontroller. When the system identifies fatigue based on sensor data, it activates the buzzer to generate an audible warning. At the same time, the vibrator produces haptic feedback, allowing the patient to feel the alert physically. This dual alert mechanism ensures that the user is effectively notified even if they do not notice the display. The buzzer is especially useful in quiet environments, while the vibrator is helpful during active movement or for users with hearing limitations. These alerts prompt the patient to stop or adjust their exercise, preventing excessive strain. By providing real-time feedback, the system enhances safety during rehabilitation. It also supports better adherence to proper

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

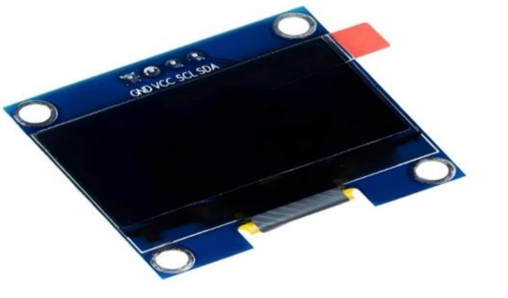
(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

exercise limits. Overall, the actuation system plays a crucial role in improving the effectiveness and safety of the rehabilitation process.

2.Biofeedback System

1.3 inch OLED

The 1.3 inch OLED display is used to provide real-time visualization of important parameters such as muscle activity, grip force, and fatigue status. It receives processed data from the ESP32 microcontroller and displays it in a clear and easy-to-read format. This allows the patient to continuously monitor their performance during rehabilitation exercises. By observing these values, users can understand their muscle condition and avoid overexertion. Thus, the OLED display plays a vital role in providing immediate feedback and improving the effectiveness of the rehabilitation process



FSR 402 (Force Sensor)

The **FSR 402 (Force Sensor)** is used in this project to measure the grip force or pressure applied by the user during rehabilitation exercises. It converts the applied force into a variable electrical signal that can be processed by the system. This data helps in evaluating muscle strength and overall performance of the patient. By monitoring changes in force over time, the system can identify signs of muscle fatigue. This ensures that the patient maintains proper exercise intensity and avoids overexertion during rehabilitation

Push button switch

The **push button switch** in this project provides a simple and convenient way for the user to control the system. It allows the patient to start or stop the rehabilitation session with ease. Additionally, it can be used to reset the system whenever required. This eliminates the need for complex interfaces or technical knowledge. Overall, it enhances user interaction by making the system more accessible and user-friendly.

POWER SUPPLY SYSTEM

3.7V Li-ion battery

The 3.7V Li-ion battery serves as the primary power source for the entire system, making it portable and suitable for wearable applications. It supplies the necessary electrical energy to all components, including the ESP32, sensors, and output devices. Since the battery is rechargeable, it allows repeated use without the need for constant replacement. Its compact size and lightweight nature make it ideal for patient-friendly rehabilitation devices. The battery ensures continuous operation of the system during exercises without interruption. It also supports mobility, enabling patients to use the device at home or on the go. Overall, the Li-ion battery plays a crucial role in maintaining reliable and efficient system performance.

© 2026 IJMRSET | Volume 9, Issue 4, April 2026 | DOI:10.15680/IJMRSET.2026.0904310

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

TP4056 charger module

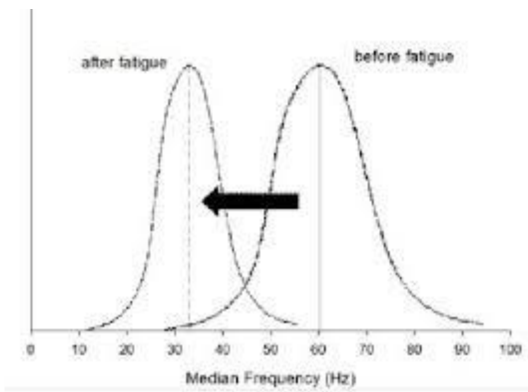
The TP4056 charger module is used in this project to safely charge the 3.7V Li-ion battery. It ensures that the battery is charged with the correct voltage and current, preventing damage. The module includes built-in protection features such as overcharge and over-discharge protection. This helps in extending the battery life and maintaining safe operation. It also prevents issues like overheating and short circuits. Overall, the TP4056 module ensures reliable and secure power management for the system.

5V booster module

The 5V booster module is used to increase the voltage from the 3.7V Li-ion battery to a stable 5V required for proper operation of the system. Since the ESP32 and some peripherals need a higher and consistent voltage, the booster ensures reliable performance. It maintains a steady output even when the battery voltage drops during usage. This helps prevent system instability or malfunction. By providing a regulated 5V supply, it supports efficient and continuous operation of all components.

III. RESULT & DISCUSSION

The proposed **IoT-based muscle fatigue detection system** is expected to:

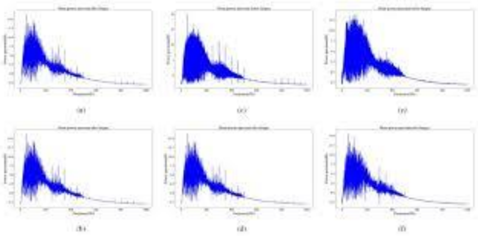


- **Accurately detect muscle fatigue in real-time** during stroke rehabilitation exercises using wearable sensors (sEMG and strain gauges).
- **Identify fatigue-induced compensatory movements early**, even in home-based rehabilitation settings.
- **Provide immediate feedback** to patients and healthcare providers for corrective actions.
- **Enable timely modification of rehabilitation protocols**, improving therapy effectiveness.
- **Reduce the risk of injury** caused by unnoticed muscle fatigue.
- **Support personalized and adaptive rehabilitation plans** based on continuous monitoring data.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



IV. CONCLUSION

The development of an IoT-based muscle fatigue detection system presents a significant advancement in stroke rehabilitation by enabling real-time monitoring and personalized therapy. Through the integration of sensors, wireless communication, and data analytics, the system provides accurate detection of muscle fatigue, allowing healthcare providers to adjust rehabilitation programs proactively.

This approach not only enhances the effectiveness of therapy but also promotes patient safety and engagement during recovery. As a scalable and cost-effective solution, this technology has the potential to revolutionize remote rehabilitation, offering continuous support and improved outcomes for stroke survivors.

V. FUTURE SCOPE

The integration of Internet of Things (IoT) technologies in healthcare, particularly in stroke rehabilitation, is a rapidly evolving field. The current project — focused on detecting muscle fatigue in stroke patients using IoT-enabled systems — offers a strong foundation for future enhancements and interdisciplinary research. Potential future developments include:

REFERENCES

1.A. K. Mishra, R. Singh, and P. K. Sharma, “IoT-based health monitoring system for rehabilitation of stroke patients,” *IEEE Access*, vol. 9, pp. 14523–14534, 2021.
2. M. J. Islam, S. M. Rafee, and T. Rahman, “Wearable EMG-based IoT device for muscle fatigue detection,” *IEEE Sensors Journal*, vol. 22, no. 8, pp. 9354–9362, Apr. 2022.
3.S. D. Gupta, P. R. Kumar, and N. Sharma, “Smart rehabilitation framework using IoT and AI for post-stroke recovery,” *IEEE Internet of Things Journal*, vol. 8, no. 11, pp. 9001–9010, Jun. 2021.
4. R. M. Enoka and J. Duchateau, “Muscle fatigue: what, why and how it influences motor function,” *Journal of Physiology*, vol. 586, no. 1, pp. 11–23, 2008.
5.P. T. K. Lee and H. Y. Wong, “IoT-enabled EMG signal acquisition and analysis for real-time muscle activity monitoring,” *IEEE Transactions on Instrumentation and Measurement*, vol. 70, pp. 1–9, 2021.
6.A. R. Reddy, K. V. Rao, and B. K. S. Kumar, “An IoT-based assistive system for continuous muscle condition monitoring in stroke patients,” *Proceedings of the IEEE International Conference on Healthcare Informatics (ICHI)*, 2020, pp. 342–348.
7.N. Patel and D. Thakker, “Real-time biofeedback using wearable sensors for physical rehabilitation,” *IEEE Transactions on Biomedical Engineering*, vol. 68, no. 7, pp. 2254–2263, Jul. 2021.
8.J. B. Yang, M. N. Hossain, and Y. C. Kim, “A cloud-connected IoT platform for electromyography-based fatigue monitoring,” *IEEE Access*, vol. 10, pp. 115230–115241, 2022.
9.P. Gupta, S. Roy, and A. Banerjee, “Machine learning-based fatigue detection using EMG signals for rehabilitation applications,” *IEEE Journal of Biomedical and Health Informatics*, vol. 27, no. 2, pp. 812–821, Feb. 2023.
10. World Health Organization, *Rehabilitation 2030: A Call for Action*, Geneva, Switzerland: WHO, 2017. [Online].Available: https://www.who.int/rehabilitation.

INNO SPACE
SJIF Scientific Journal Impact Factor

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

निस्केयर NISCAIR

INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH

IN SCIENCE, ENGINEERING AND TECHNOLOGY

| Mobile No: +91-6381907438 | Whatsapp: +91-6381907438 | ijmrset@gmail.com |