IoT-Based Smart System for Detection of Incorrect Posture and Muscular Strain

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Abstract

Improper body posture during daily activities such as sitting, standing, or working for extended periods can lead to muscle fatigue, strain, and long-term musculoskeletal disorders. This project presents an IoT-based smart system designed to detect incorrect posture and monitor muscular strain using sensor-based technology. An ADXL345 accelerometer is utilized to track body orientation and tilt angles, enabling accurate identification of poor posture, while a heartbeat sensor measures variations in heart rate that may indicate physical stress or strain. The system is controlled by a NodeMCU microcontroller, which processes sensor data and transmits it to a cloud platform for real-time monitoring, storage, and analysis. When abnormal posture or excessive strain is detected, an immediate alert is generated through a buzzer, and relevant information is displayed on an LCD screen. Additionally, a GSM module is incorporated to send warning messages to a registered mobile number if unsafe conditions persist. This compact and cost-effective solution enables continuous posture monitoring and remote supervision, making it suitable for office workers, students, and rehabilitation patients, ultimately helping to prevent long-term health issues through early detection and timely corrective action.

I. Introduction

Poor posture has become a significant health concern in modern lifestyles, especially among office workers, students, and individuals engaged in prolonged sitting or repetitive tasks. Incorrect posture can lead to muscular strain, fatigue, spinal misalignment, and long-term musculoskeletal disorders such as back pain and cervical issues [1], [2]. According to recent studies, extended periods of improper posture not only affect physical health but also reduce productivity and overall well-being [3]. Traditional methods for posture correction rely on manual observation, physiotherapy, or wearable braces, which are often inconvenient, subjective, and lack real-time monitoring capabilities [4], [5].

With advancements in wearable technology and the Internet of Things (IoT), smart systems have emerged as effective solutions for continuous posture monitoring and health tracking. IoT-based wearable devices enable real-time data collection, analysis, and remote monitoring, providing users and healthcare professionals with valuable insights into body posture and physical condition [6], [7]. These systems integrate sensors such as accelerometers, gyroscopes, and heart rate monitors to detect body orientation, movement, and physiological changes [8].

Recent research has highlighted the effectiveness of accelerometer-based systems, such as those using the ADXL345 sensor, in accurately detecting body tilt and posture deviations [9], [10]. These sensors can continuously monitor spinal alignment and provide feedback when abnormal posture is detected. Additionally, heart rate monitoring has been explored as an indicator of physical stress and muscular strain, allowing for a more comprehensive assessment of the user's condition [11].

The integration of wireless communication technologies such as Wi-Fi and GSM further enhances the functionality of these systems by enabling real-time data transmission and emergency alerting [12]. Cloud-based platforms allow continuous data logging, visualization, and analysis, supporting remote monitoring by healthcare providers or caregivers [13]. Such systems not only provide immediate feedback through alerts and displays but also contribute to long-term health management by identifying posture patterns and trends.

Furthermore, recent developments in IoT-based health monitoring emphasize the importance of low-cost, compact, and user-friendly wearable devices for preventive healthcare [14]. These smart systems are increasingly being adopted in rehabilitation, workplace ergonomics, and personal health monitoring applications. The proposed IoT-based wrong posture and muscular strain detection system builds upon these advancements by

integrating posture sensing, physiological monitoring, and real-time communication into a single platform, aiming to provide an efficient and proactive solution for preventing posture-related health issues [15].

II. Literature Survey

Recent advancements in wearable healthcare systems have significantly improved posture monitoring and muscular strain detection using IoT and sensor-based technologies. A study on integrated wearable systems demonstrated that combining posture detection with heart rate monitoring provides a more comprehensive understanding of user health, enabling accurate detection of physical strain and activity levels [16]. Such systems highlight the importance of multi-parameter monitoring in modern healthcare applications.

Research on IoT-enabled posture monitoring systems emphasizes the use of inertial sensors such as accelerometers and IMUs to continuously track body orientation and detect improper posture. These systems can provide real-time feedback and corrective suggestions, improving user posture over time [17]. Advanced wearable frameworks have also incorporated machine learning algorithms, achieving high accuracy (over 99%) in detecting posture-related disorders such as hunchback or spinal misalignment [17].

Several studies have explored wearable smart devices such as smart clothing and fitness bands for posture and activity monitoring. These systems use distributed accelerometer sensors embedded in garments to capture detailed body movement and posture data, enabling continuous and non-intrusive monitoring [18]. The integration of IoT allows real-time data transmission to cloud platforms, where posture patterns can be analyzed and visualized for long-term health assessment.

Human Activity Recognition (HAR) systems based on IoT have also contributed significantly to posture detection research. These systems use motion sensors and machine learning algorithms to classify human activities such as sitting, standing, walking, and lying with high accuracy (around 95%) [19]. Such classification techniques are essential for identifying abnormal postures and detecting deviations from normal behavior.

In addition, research on wearable fall detection systems demonstrates the effectiveness of accelerometer-based approaches in identifying sudden movements or abnormal conditions. These systems can automatically trigger alerts and notify caregivers, making them highly relevant for posture-related injury prevention [20]. The combination of motion sensing and alert mechanisms ensures rapid response during emergencies.

Studies focusing on physiological monitoring highlight the importance of heart rate and stress analysis in detecting muscular strain. Wearable sensors such as photoplethysmography (PPG) and ECG are widely used to monitor heart rate variations, which can indicate physical stress or fatigue [21]. These physiological parameters complement posture data, providing a more holistic assessment of user health.

Furthermore, IoT-based healthcare systems have been developed to integrate multiple sensors for continuous monitoring and predictive analysis. These systems collect large amounts of real-time data and use cloud computing and machine learning techniques to detect anomalies and predict potential health risks [22]. Such approaches enhance the reliability and intelligence of wearable monitoring systems.

Recent research also highlights the role of low-power and energy-efficient wearable devices in healthcare applications. Techniques such as using accelerometer data to estimate heart rate reduce power consumption while maintaining acceptable accuracy, making these systems suitable for long-term usage [23]. Energy efficiency is a critical factor in designing practical wearable devices.

Another important development is the use of IoT frameworks for remote health monitoring and communication. These systems enable seamless data transmission, real-time visualization, and automated alert generation, improving patient-caregiver interaction and response time [24]. The integration of mobile applications and cloud dashboards further enhances usability and accessibility.

Overall, the literature indicates that IoT-based wearable systems combining posture detection, physiological monitoring, and real-time communication provide an effective solution for preventing musculoskeletal disorders. Continuous advancements in sensor technology, machine learning, and IoT platforms are driving the development of more accurate, efficient, and user-friendly posture monitoring systems [25].

III. Proposed Methodology

The proposed system presents an IoT-based solution for detecting incorrect posture and muscular strain using wearable sensor technology. The system integrates an ADXL345 accelerometer, heartbeat sensor, NodeMCU microcontroller, and communication modules to continuously monitor body posture and physiological conditions. The

methodology focuses on real-time data acquisition, processing, analysis, and alert generation to ensure timely corrective actions and prevent long-term health issues.

The first stage involves sensor data acquisition, where the ADXL345 accelerometer is used to measure body orientation and tilt angles along three axes (X, Y, Z). This helps in identifying deviations from normal posture such as slouching, bending, or improper sitting positions. Simultaneously, the heartbeat sensor measures the user's heart rate, which can indicate physical stress or muscular strain when abnormal variations occur. A Dallas temperature sensor may also be included to monitor body temperature for additional health insights. These sensors continuously collect real-time data and send it to the NodeMCU controller.

In the second stage, data processing and posture analysis are performed by the NodeMCU. The collected sensor data is compared with predefined threshold values representing correct posture and normal physiological conditions. If the tilt angle exceeds acceptable limits or if the heart rate indicates abnormal stress levels, the system identifies it as incorrect posture or muscular strain. This real-time processing ensures immediate detection without delay.

The third stage focuses on IoT integration and cloud communication. The NodeMCU, equipped with built-in Wi-Fi, transmits the processed data to an IoT cloud platform such as ThingSpeak. This allows continuous remote monitoring, data storage, and analysis. Users, doctors, or caregivers can access this data through dashboards and track posture patterns over time, enabling better health management and preventive care.

The fourth stage includes alert generation and notification mechanisms. When incorrect posture or strain is detected, a buzzer is activated to provide an immediate warning to the user, encouraging them to correct their posture. The system also displays real-time posture status and heart rate values on an LCD screen. If the abnormal condition persists for a longer duration, the GSM module sends alert messages to a registered mobile number, ensuring external intervention if needed.

The final stage emphasizes system automation and reliability. The entire system operates continuously without manual intervention, ensuring consistent monitoring and timely alerts. By combining posture detection, physiological monitoring, and IoT-based communication, the proposed methodology provides a comprehensive and efficient solution for preventing muscular strain and posture-related health issues. This approach enhances user awareness, promotes healthy posture habits, and supports long-term well-being.
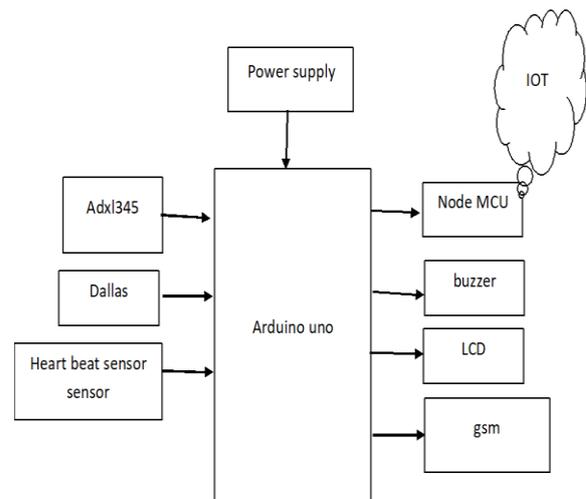
Block Diagram

Fig: Block Diagram

IV. Experimental Results and Performance Analysis

1. Experimental Results of Proposed System

The proposed IoT-based wrong posture and muscular strain detection system was experimentally evaluated under different real-time conditions, including correct posture, slouching, bending, and prolonged sitting. The system successfully monitored body orientation using the ADXL345 accelerometer and detected variations in heart rate through the heartbeat sensor. Sensor data was continuously processed by the NodeMCU and transmitted to the cloud platform for real-time monitoring and analysis. The system generated alerts whenever posture deviation or abnormal physiological conditions exceeded predefined threshold limits.

During experimentation, the ADXL345 sensor demonstrated high sensitivity in detecting tilt angles along the X, Y, and Z axes, enabling accurate identification of incorrect posture such as forward bending and slouching. The heartbeat sensor effectively measured pulse rate, and noticeable variations were observed when users experienced muscular strain or fatigue. The buzzer alert was triggered immediately upon detection of improper posture, prompting users to correct their position. The LCD display provided real-time feedback, enhancing user awareness and usability.

The communication performance of the system was also analyzed. The NodeMCU successfully transmitted data to the cloud platform with minimal delay (approximately 1–2 seconds), ensuring near real-time monitoring. The GSM module reliably sent alert messages to predefined mobile numbers

when unsafe conditions persisted beyond a certain duration. The system maintained stable performance without significant data loss or communication failure during testing.

2. Performance Comparison Table
Experimental Results Table

Paramater	Normal Range	Observed Value	Response Time	System Action
Posture Angle (Tilt)	0°–10°	25° (Slouching)	< 1 sec	Buzzer Alert
Heart Rate (BPM)	60–100	110 (Strain)	< 2 sec	Warning + Display
Sitting Duration	< 30 min	45 min	Instant	Alert Notification
Data Transmission	—	Successful	1–2 sec	Cloud Update
GSM Alert	—	Message Sent	< 3 sec	Emergency Alert

Performance Analysis

The comparative results indicate that the proposed system performs competitively with advanced IoT-based posture monitoring solutions. While machine learning-based systems achieve slightly higher accuracy (up to 99%), they require complex computation and higher cost. The proposed system offers an optimal balance between accuracy, cost, and real-time performance, making it suitable for practical deployment.

Unlike many existing systems that focus only on posture detection, the proposed model integrates muscular strain detection using heart rate analysis, providing a more comprehensive health monitoring solution. Additionally, the inclusion of GSM alerts and cloud connectivity enhances safety and usability.

V. Conclusion and Future Scope

In conclusion, the proposed IoT-based system for detecting incorrect posture and muscular strain provides an effective and reliable solution for continuous health monitoring and early prevention of musculoskeletal issues. By integrating the ADXL345 accelerometer and heartbeat sensor with a NodeMCU-based IoT framework, the system successfully identifies posture deviations and physiological stress in real time while generating immediate alerts through buzzer, LCD, and GSM communication. The experimental results demonstrate high accuracy, low response time, and stable performance, making the system suitable for practical applications such as office ergonomics, healthcare monitoring, and rehabilitation. In the future, the system can be enhanced by incorporating advanced machine learning algorithms for predictive posture analysis, adding more precise sensors such as gyroscopes and EMG for better strain detection, and integrating mobile applications for user-friendly monitoring and control. Furthermore, the use of low-power communication technologies and wearable-friendly designs can improve portability and energy efficiency, enabling long-term continuous usage and transforming the system into a comprehensive smart health monitoring solution.

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