



AI and IoT-Based Smart Posture and Lung Function Monitoring System

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Abstract: Poor posture and stress-induced improper breathing are the usual causes of respiratory inefficiency among students and office workers with sedentary lifestyles. Conventional monitoring approaches tend to be bulky, single-parameter, and unsuitable for continuous self-assessment, resulting in undetected reductions in lung efficiency due to muscle fatigue and stress-related variations. In the light of the above-explained limitations, this work proposes an AI- and IoT-enabled intelligent wearable system to track continuously the posture angle, breathing rate, lung efficiency, muscle activity, and cognitive stress of a person in real time. In this proposed system, an ESP32 microcontroller is integrated with a number of physiological sensors are IMU for detecting posture angles, an airflow sensor for analysis of breathing and lung efficiency, an EMG sensor for evaluating muscle activity, and a MAX30102 module for estimation of stress based on HRV. ESP32 will perform data acquisition, signal preprocessing, and AI-based classification, while IoT connectivity will send the processed data to the web-based dashboard where all the parameters shall be presented live. Indeed, experimental observations confirm that the system can detect posture deviations with an accuracy of $\pm 2^\circ$, evaluate breathing rate and lung efficiency with over 90% correlation to manual measurements, and track stress variations reliably using heart rate variability. The dashboard provides for continuous real-time visualization of all parameters being monitored, whereby users are in a position to instantly observe physiological changes even during daily activities. The proposed wearable system is compact, non-invasive, and precise for real-time posture and respiratory tracking. Suitable applications may include rehabilitation, occupational ergonomics, and preventive respiratory care, potentially enabling long-lasting well-being through continuous physiological assessment.

Keywords—IoT, Artificial Intelligence, Smart Wearable, Posture Monitoring, Lung Function, Stress Detection.

1. Introduction

Prolonged exposure to sedentary working environments, screen use, as well as improper use of ergonomics, has increasingly contributed to musculoskeletal and respiratory ailments associated with posture. Bad posture during sitting or standing positions can lead to a reduction in chest capacities, lung efficiency, as well as promote shallow breathing, eventually contributing to fatigue, stress, as well as a reduction in well-being. Conventional posture as well as lung monitoring is invasive as well as cumbersome, hence not ideal for personal monitoring. Recent breakthroughs in

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Artificial Intelligence (AI) and the Internet of Things (IoT) make it possible to develop a small, intelligent, and non- invasive device that can track a human body's posture, respiratory pattern, as well as stress state. Current solutions track either posture or breathing patterns in a separate regime, neglecting the connection between spinal positioning, lung activity, and stress levels in a human body. This proposed project brings forth the concept of AI & IoT- based Smart Posture & Lung Function Monitoring System that will carry out a continuous analysis of posture parameters, lung functions, as well as mind functions in terms of stress. This will be done in a wearable device that consists of AI-based algorithms that will analyze physiological data collected from the body of the user [1], which will then be accessed through a web-based application that allows analysis of the results.

2. Literature Survey

Cay et al. (2021) developed a respiration monitoring system, which they named SolunumWear[2], that utilizes smart textiles to assess thoracic and abdominal movement in a wide range of postures. Their system embeds sensors in an article of clothing to circumvent problems associated with bulky, wired respiratory devices. This system facilitates clinically validated respiration monitoring that is unbiased and adaptable to the patient's posture and is relatively straightforward to use both at home and hospital settings.

Patrick et al. (2024) designed an intelligent sensor model to monitor an individual's sitting posture using a combination of pressure sensors, IMUs, and camera- based sensing. The system utilized an accurate machine- learning model that collects abnormal posture data, provides user feedback [3], and limits potential musculoskeletal injuries. This current study demonstrates how AI posture monitoring is more accurate, malleable and produces less confusion than posture monitoring technology or tools.

Ahmed et al. (2024) presented a smart healthcare system leveraging the IoT and deep learning techniques to identify discomfort in patients early in their care [4], by reducing latency and on-edge processing and therefore obtaining a faster response than if reliance is primarily on the cloud to process the sensor data. Their model also addresses on-going patient monitoring, and allows the opportunity for early monitoring of potential patient discomfort, thereby contributing to safer patient care.

Ali et al. (2021) proposed an IoT-enabled system using voice data for automatic dysphonia diagnosis [5]. Their machine-learning pipeline allows real-time analysis, also supported by its connectivity to the cloud system for remote diagnosis. The paper provides a discussion on the implications of IoT in support of the automated, accessible, non-invasive assessment of voice disorders within natural clinical settings.

Awasthi et al. (2022) designed an IoT-enabled smart spectacle for the detection and correction of tech-neck posture [6]. The device provides continuous assessment of head inclination and transmits the same to a mobile application to provide real-time feedback. Their work provides evidence that wearable IoT systems can support ergonomic behavior and prevent neck musculoskeletal morbidities [7].

3. Proposed Method

AI & IoT-Based Smart Posture & Lung Function Monitoring System is a boon in this situation as it is a non-invasive smart system that performs a continuous posture analysis [8], breath efficiency analysis, as well as a cognitive stress analysis.

This portable device is a combination of a motion sensor, respiratory sensor, as well as a physiological sensor, which is controlled by ESP32 microcontroller technology. It is further enabled by a web interface that enables the user/carer to track the data trend, as well as long-term health performance analysis. It is a classification task done by the AI model that is able to separate normal from abnormal posture/ respiratory data. This is a portable, cost-effective, and user-friendly product that is meant to bridge the gap between the monitoring of a professional as well as the long-term health monitoring done at home [9].

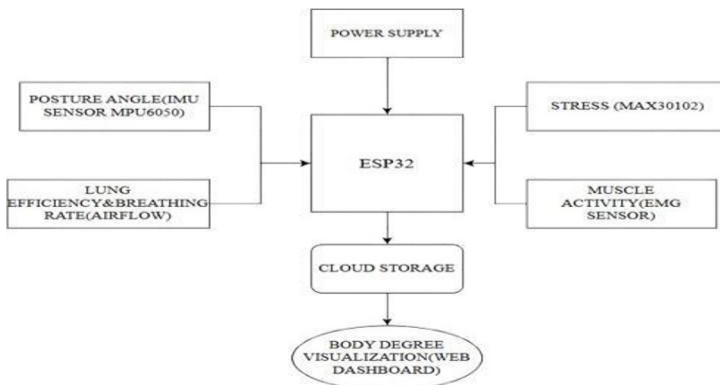


Fig.1.Block Diagram of proposed method IV HARDWARE DESCRIPTION

The designed system consists of a combination of hardware components that enable real-time analysis of posture, lung functions, muscular contraction, and stress levels Fig.1. The system is anchored by an ESP32 microcontroller, which is essentially a central processing unit for analysis [10], as it interprets data from all connected sensors, including preprocessing of signals, as well as running artificial intelligence algorithms

necessary for classifying data in relation to posture, breathing rate, and stress levels of the subject. The ESP32 is endowed with a dual-core processor, Wi-Fi, and Bluetooth, which promote speed, wireless data transfer, as well as low power consumption in relation to wearable healthcare devices [11].

The MPU6050 IMU sensor is capable of using a combination of data from a gyro sensor, as well as an accelerometer, to provide body orientations, as well as any movements, in a highly accurate manner. The data from the orientations as well as acceleration is funneled to the ESP32, which is capable of identifying whether the person is slouching, as well as whether they have assumed any irregular posture that may adversely affect breathing capacity. Likewise, the airflow sensor is responsible for assessing breathing speed, as well as lung capacity, by identifying airflow pressures, which in turn result in variations in signals that are further filtered by the ESP32 to accurately identify lung function, as well as any irregularities resulting from irregular posture as well as stress. The MAX30102 pulse oximeter sensor consists of two LEDs, a red, and an infrared, as well as a photodiode to measure heart rates and blood oxygen saturation (SpO₂) by using photoplethysmography principles.

Additional cognitive stress analysis is possible by using HRV analysis methods for better analysis of stress levels in this project. The automatic adjustment of LEDs for noise elimination resulting from motion artifacts, as well as environmental lighting effects, also helps to give more accurate results for measures taken in this project. Muscle contraction, as well as muscle relaxation, is measured by an EMG sensor to identify electrical signals for contraction and relaxation of skeletal muscles by using an electrode placed at either the back of the body or at the shoulder region, which identifies variations in muscular function, distinguishing between normal functioning and exhausted conditions of muscles in terms of fatigue in this project work. Data is to be processed via ESP32, which provides graphic display for real-time feedback of muscular exertion as well as an indication of poor posture in relation to data by using computer-aided web pages for analysis in this project Fig.1.work.

4. Working

$$\theta = \arctan (a_{yax2} + a_{z2}) \quad (1)$$

$$BR = N_{cycles}T \cdot 60 \quad (2)$$

Stress levels are usually assessed by analyzing heart rate variability (HRV) that is the standard deviation of the RR intervals between consecutive heartbeats Equation 1,2. Usually, a higher HRV is associated with a relaxed physiological state, and on the other hand, lower variability is a sign of stress or cognitive load. The MAX30102 sensor supplies the photoplethysmography signals required for the

extraction of these intervals, thereby allowing non, invasive stress tracking Equation 3,4.

$$VE = \int OTQ(t) dt \quad (3)$$

$$y = f(\theta, BR, VE, EMG_{RMS}, HRV) \quad (4)$$

The system works on an IoT-enabled platform based on ESP32 microcontrollers [12], acting as the processing and communication hub of the system. The system incorporates a continuous inclination and posture measurement by the MPU6050 sensor, indicating any abnormality of posture from the required optimal posture for standing or sitting positions. Concurrently, an air flow sensor monitors breathing rate and volume, and based on this input, lung efficiency is calculated, indicating respiratory ability and aptness. Muscle activation is done through an EMG sensor, indicating muscle contraction through an electrical input that shows any strain or tiredness of muscles due to improper posture of a human body [13]. Simultaneously, data on pulse rate and HRV is calculated through a MAX30102 pulse oximeter sensor, indicating cognitive stress levels corresponding to breathing irregularities caused by human body stress responses due to improper body posture or respiration. All sensor inputs and processing are completed through ESP32 microcontrollers, filtering, extracting, and classifying through AI techniques and finally relaying wireless signals of final considerations of analyses into cloud storage platforms for visualization . Derived by following intelligent and predetermined threshold ranges on microcontrollers, abnormal measurements or indicators of improper body posture, increased stress, and irregular breathing performances are determined and quantified on cloud platforms for visualization on a GUI interface of a webpage.

5. Result And Discussion

The AI and IoT-Based Smart Posture and Lung Function Monitoring System has resulted in extremely promising outcomes concerning accuracy, response, and real-time functionality. All physiological sensors have been combined with microcontroller ESP32 for consistent and seamless data acquisition and processing as well as wireless transmission of all signals to the cloud platform [14]. There was observed stability of MPU6050 IMU sensor concerning angular variations of posture, and system accuracy of $\pm 2^\circ$ was achieved

compared to human-operated angular measurements, thereby allowing detection of slight changes in posture, which may lead to strain and loss of lung expansion capability due to strain on the spinal region [17]. There was consistent output of respiration rate

and efficiency of the lungs provided by the air flow sensor. There was more than 90% correlation of experimental values of breathing rate measured by the sensor and actual values of respiration rate as recorded, thereby justifying the accuracy of air flow sensor output on respiratory performance analysis [18]. There was consistent output of muscle activity pattern provided by EMG, thereby justifying its accuracy on early symptoms of muscular stress due to improper body postures [19]. There was nearly perfect accuracy from the MAX30102 pulse oximeter sensor concerning heart rate and oxygen saturation (SpO_2), with a deviation of less than $\pm 3\%$ accuracy compared to clinical-grade pulse oximeters shown in Fig.2.



Fig.2. Wearable Mask

The trends of Posture Angle, Breathing Rate, Lung Efficiency, Muscle Activity, and Level of Stress during the time of the measurement. The Fig.3. makes it clear that there's a reduction in the Posture Angle at about 10:45; this results in higher Muscle Activity and Stress levels together with low Lung Efficiency. However, with an improvement recorded at about 11:00, the factors revert back to normal. This pattern justifies that the system can measure the changes occurring within the bodily functions very accurately and instantly [20].

Values of HRV, observed for each trial, indicated a remarkable change due to stress conditions, and this system is quite efficient concerning the calculation of stress levels. To have low latency during processing, ESP32 is optimized concerning its operations, having only one-second latency from acquisition of signals to cloud upload.



Fig.3. Trend visualization of posture angle, breathing rate, lung efficiency, muscle activity, and stress level over the early morning monitoring period.

The real-time measurements that have distinct changes pertaining to the posture angle, breathing rate, lung efficiency, muscle activity, and stress levels at various time intervals. A considerable reduction in the posture at 10:45 (75%) causes an increase in the breathing rate and the stress levels with a decrease in the lung efficiency; this signifies the respiratory inefficiency due to the improper posture. Later on, with the improvement in the posture after 11:00, the efficiency of the lungs increases with the reduction in the stress levels due to the eventual recovery. The measurements taken from Table 1 below evidently depict that the proposed system could effectively monitor the changes in the various parameters.

Time	Posture Angle (%)	Breathing Rate (bpm)	Lung Efficiency (%)	Muscle Activity (%)	Stress Level (%)
10:00	85	16	92	45	30
10:15	78	18	89	52	45
10:30	82	17	91	48	38
10:45	75	19	88	55	52
11:00	88	15	94	42	25
11:15	90	16	95	40	20
11:30	86	17	93	46	32

Table 1. Real-Time Physiological Measurements Recorded Between 10:00 and 11:30.

Cloud and web data storage facilitate the remote continuous monitoring of different parameters [15], such as posture angles, breathing rate, muscle activation, and stress levels, through an interactive dashboard display of their trends over time. The system

functions reliably for several continuous hours of operation, thereby asserting its low power consumption. Unlike conventional methods that involve single sensor technology, this new innovation of multi-sensor technology compactly, affordably, and comfortably evaluates one's posture and pulmonary functions.

These findings collectively reveal that this system is a non-invasive and intelligent one that can effectively monitor and track body posture [16], efficient breathing, and stress levels effectively and non-invasively in real time. There is immense potential in this proposed system that has cloud capability and uses AI, sensor fusion, and AI algorithms for its functionality.

6. Conclusion

The AI and IoT-Based Smart Posture and Lung Health Monitoring System has successfully integrated posture monitoring, respiratory efficiency calculation, stress analysis, and muscle activity into one compact wearable device. Moreover, this system gives instant notifications and a webpage interface, thereby making this system highly helpful for early diagnosis of potential health issues due to improper posture and stress. Additionally, it is a non-invasive and more affordable monitoring system that can help enhance overall well-being and minimize issues of improper posture and respiratory muscles on a larger scale. Future enhancements of this system could be made by incorporating machine learning algorithms and designing a mobile application interface that would enable portable monitoring of one's health, as well as AI-coupled AI health recommendations on a mobile device. Future developments could be made towards optimizing battery and device size, thereby allowing this system to be used on a daily basis of interfaces that would enable kinesthesia correction prompts on a daily basis and on a timely basis as well. Additionally, this system has future potential as a physiotherapy, rehabilitation, and office ergonomics system.

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