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Posture Monitoring and Back Pain Alert System

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Abstract- Back pain from sitting too long and bad posture is now one of the most common health problems for students, office workers, and computer users. Posture-tracking cameras and high-tech ergonomic furniture are some of the more common solutions, but they can be expensive, hard to set up, or raise privacy concerns. This paper presents an IoT-based Posture Monitoring and Back Pain Alert System developed with an ESP32 microcontroller, a flex sensor, a force sensor, and an MPU6050 accelerometer–gyroscope module. It is a cost-effective and user-friendly alternative. A Flutter mobile app collects the user's height and weight, which lets the system automatically set sensor thresholds for different body types. The ESP32 checks your posture in real time and sends sensor data to the app over Wi-Fi. If the app notices that you are slouching, putting too much pressure on your back, or tilting your torso too much, it will immediately show a posture alert message, telling you to fix the problem. The system runs on a Li-ion battery with a TP4056 charging module, which makes it portable and allows for continuous use. Experimental observations demonstrate that the personalized threshold mechanism markedly diminishes false alerts while enhancing comfort and user acceptance. The suggested design is a good, cheap, and private way to fix your posture and keep your back from hurting.

Keywords: Posture Monitoring, Back Pain Prevention, ESP32, Flex Sensor, Force Sensor, MPU6050, IoT System, Flutter Mobile Application, Personalized Thresholds, Ergonomics, Li-ion Battery, TP4056 Charger.

I. INTRODUCTION

Health problems related to posture have become more common in the last few years because of changes in lifestyle, like working in sedentary environments, spending too much time in front of screens, and working from home. Global health statistics show that millions of people have musculoskeletal disorders, and lower back pain is one of the most common ones.

Bad sitting posture puts uneven stress on the spine, makes muscles tired, slows circulation, and can lead to long-term orthopedic problems. This is why it's important to always be aware of your posture.

Accurate posture analysis is done by traditional posture correction systems which include the camera based tracking systems out, but they do have it out in high cost, complex set up and also issues of privacy which in some settings like private or shared indoor spaces is a big issue. Also we see that wearable posture belts and sensor straps may interfere with natural movement and cause discomfort especially over long term use. These issues has brought forth the development of the sensor driven, Internet of Things based, non-intrusive monitoring systems which we see to also protect user privacy, comfort and at the same time be economic.

This paper discusses the implementation of an IoT-integrated Posture Monitoring and Back Pain Alert System, namely the MPU6050, which accelerometer-gyroscope modules. MPU6050 facilitates monitoring the user's upper-body. It consists of an ESP32 microcontroller applied in conjunction with a flex sensor designed to measure curvature of the spine, and a force sensor for monitoring back pressure. The ESP32 is armed with Wi-Fi to maintain constant communication with the mobile device to receive and process real time sensor data. The mobile application interface is designed and developed using the Flutter framework. The user gives their height and weight instead of making manual hardware adjustments. The application issues an immediate visual alert requiring corrective measures when detecting poor posture (i.e., slouching, excessive pressure on the backrest, or abnormal torso tilt).

A system powered by a 3.7V Li-ion battery and a TP4056 charging module is small enough, and the battery is rechargeable enough, for daily use. The provided approach is an effective and convenient method for motivating users to adopt healthy sitting habits and to prevent back pain due to poor posture and, at the same time, ensures privacy, is inexpensive, and offers personalized monitoring.

II. LITERATURE REVIEW

Posture Detection and Monitoring Systems

In their sensor enabled framework for posture Monitoring, Park et al. report that which gyroscopes and Accelerometers do play a key role in the efficient tracking of spinal alignment [1]. Also in that light, Gupta and Kaur put forth the importance of ergonomic interventions which they do via a put forth low cost flex sensor solution to track posture deviations in office workers [2]. For accuracy and user comfort Ahmed et al. report on the integration of posture correction algorithms into wearable technology [3].

IoT-Enabled Health Monitoring

With ESP32-class microcontrollers sending continuous health data uploaded to the cloud for remote access, Zhou et al. report on the success of IoT based solutions in real time posture tracking [4]. Sharma et al. present the value of smart phone notifications for preventive health care in a study which also included wearables and the Internet of Things which they used to send out back pain alerts [5]. Also reported by Banos et al. are the results of studies which look at how best to use the IoT to improve patient compliance with health care regimens [6].

Sensor Technologies for Posture Analysis

Lee et al. have examined the advantages of flex and stress sensors as applied to the posture application in determining the distribution of bending and pressure along the spine [7]. Atalay et al. also illustrate the role of fabric force sensors in ergonomic assessments, in addition to the fact that they are very discreet and therefore ideal for long-term monitoring [8]. At the same time, Li et al. examine the use of MPU6050 for real time monitoring of tilt-angle using Inertial Measurement Units (IMUs) for tilt angle detection which we report accurate posture classification across many orientations [9].

Adaptive Thresholding and Personalization

To account for individual differences Rajesh et al. report that in the case of user weight based calibration models which use potentiometers to adjust force thresholds [10]. Also we see in the work by Wang et al. they put forth a very similar approach which improves system performance and reduces false alarms [11].

Smartphone Notifications and Alert Mechanisms

Mukherjee et al. put forth a mobile integrated alerting system which at the time of detection of wrong posture gives out vibrating and text based notifications [12]. Also Singh and Patel use cloud based notification APIs to give out real time warnings which in turn gives the users action able feedback on their posture health [13].

Comprehensive Reviews on Posture and Ergonomic Systems

Chen et al. did a in depth study of wearable posture monitoring tech and put forth what are the issues and also the possibilities of sensor based systems

[14]. Also Kumar et al. report on IoT based health care solutions which they note have a large growth element in the area of posture monitoring as a part of preventive ergonomics.

Low-Cost IoT-Enabled Smart Chairs
Islam, Hossain, and Rahman report on an economic Internet of Things smart chair that which has in chair mounted sensors which constantly report spinal alignment, which they put into home and office settings. Also in this space, Chen, Wu, and Liu look at IMU based posture recognition which reports on the success of very small inertial units to accurately record tilt and bend in a wide range of seating situations.

Sedentary Worker Health Monitoring
In their study of IoT enabled health care which Patel and Shah report that in systems which support seated workers importance of early identification of musculoskeletal issues and low back strain. With smart seat pressure sensing that which is Suresh, Babu, and Kumar into this strategy instant feedback on ergonomics and spinal load.

Ergonomic Chair Implementations
To better present their research on improved posture correction, Ahmed, Uddin, and Rahman put forth the concept of an IoT integrated ergonomic chair for remote workers which includes multi-sensor feedback and adaptive thresholding. In another study Verma and Kumar report on wearable sensor based systems which they say have see an increase in accuracy and user compliance by use of real time tracking of posture and back pressure.

Advanced Tilt Detection and Neural Network Integration
Wang, Zhou, and Li report they have improved detection of small changes in seating position by use of MPUL50 tilt sensors in combination with neural networks for posture classification. Finally Rani and Singh present an IoT based posture detection system for students which they report does very efficient job of alert delivery and body weight adaptation.

Cloud-Connected and Real-Time Monitoring
Lin, Deng, and Chen exemplifies the use of remote posture supervision within the field of telehealth and they employ cloud-based wearable devices for spinal monitoring. An entire system for posture detection that is IoT-based is presented by Zhao, Xu, and Zhang. Such a system facilitates reliable monitoring and the issuing of instant alert notifications.

III. PROPOSED METHODOLOGY

The proposed system aims to provide real-time posture monitoring utilizing non-intrusive sensors along with an IoT-based microcontroller, and provide corrective feedback. The architecture of the system comprises communication & user interface layer, processing layer and sensing layer. The system interfaces, collect posture data, and alert the user of detected bad posture.

System Components

- ESP32 is the central processing unit, receiving, analyzing sensor data, and relaying information the Flutter mobile app via Wi-Fi. Dual core architecture allows reading and syncing data with the network without lag.
- The flex sensor measures the degree of spinal flexion and slouching by bent resistance. The sensor is placed at the location of the upper-back curve to best indicate posture shifts.
- The system detects and records the internal load of the chair user's back by quantifying the backrest pressure and assessing the force applied by the user. Backrest pressure clearance suggests a resting state while the position in the center of the backrest indicates frontal sitting posture.
- The MPU6050 records the alignment of with the tilt of the chair in three different axis directions which the system detects as forward tilt as well as lean left/right posture deviations.
- A rechargeable 3.7V Li-ion battery powers the system and TP4056 provides safe and reliable charging of the battery ensuring the system is portable and highly usable.
- The mobile software is used to retrieve the user's height and weight needed for automatic

adjustments to the sensor thresholds. It also allows to get and visualize the position alerts and sensor readings from ESP32 in real-time over Wi-Fi.

Algorithm Summary

- Initialize ESP32, sensors, and Wi-Fi communication.
- Receive user height and weight from Flutter app.
- Compute flex and force thresholds using personalized scaling.
- Continuously reads Flex sensor value, Force sensor value, MPU6050 accelerometer values.
- Compute tilt angle and Compare sensor values with thresholds
- Combine triggered alerts into a single meaningful message.
- Send sensor values and alert message to the Flutter app.
- Repeat steps 4–8 at 1-second intervals for real-time response.

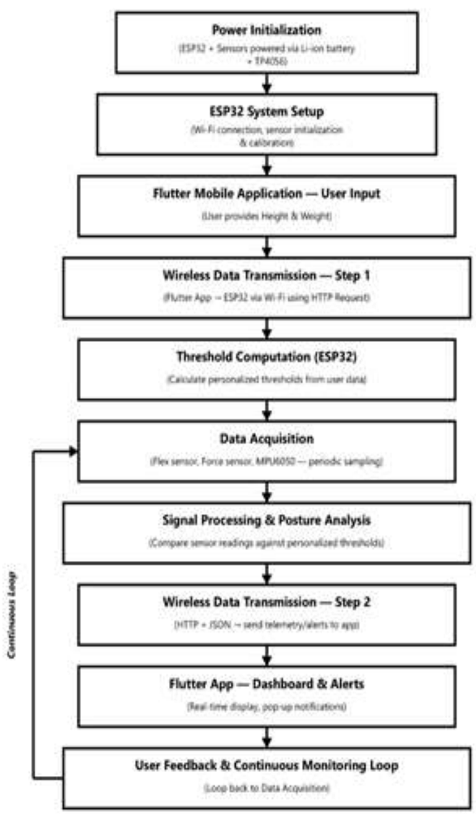

Fig.1.Block diagram of the proposed Posture Monitoring and Back Pain Alert System

The block diagram of the proposed system is shown in Fig.1. The ESP32 is powered by a Li-ion battery, charges via a TP4056 module, and receives data from flex, force, and MPU6050 sensors. Users enter their height and weight into the Flutter application, which is transmitted to ESP32 to determine personalized thresholds. While the system is running, ESP32 analyzes real-time data from the sensors and compares those with the thresholds to identify if the user is slouching, applies excess pressure to their back or is leaning. Upon identification of poor posture, the system alerts the user via the Flutter application over Wi-Fi and the Android device.

System Workflow

Sensor Data Acquisition

1. Flex sensor resistance values.
2. Force sensor pressure output.
3. MPU6050 accelerometer readings.

Custom Threshold Adjustment

1. The user enters height (cm) and weight (kg) into the app.
2. These values are sent to the ESP32.
3. The ESP32 calculates personalized thresholds.
4. This ensures lower false alerts across different body types.

- **Posture Evaluation Logic**

1. Flex sensor reading is compared with the computed flex threshold.
2. Force sensor reading is evaluated against the personalized force threshold.
3. Tilt angle is calculated using

   Tilt Angle = arctan (ax/az) · 180/π [∘].

- **Alert Generation**

1. If any threshold is exceeded the ESP32 constructs a single consolidated alert message summarizing detected issues.

- **Notification and User Feedback**

1. The ESP32 sends updated readings and alert messages to the Flutter app in JSON format.

IV. WORKING PRINCIPLE

The Posture Monitoring and Back Pain Alert System uses a sensing, processing, and alert mechanism to continuously monitor the user's sitting posture and provide immediate corrective feedback. The following is a description of the working principle.

Posture Sensing

Three sensors are used by the system to track posture in real time. The flex sensor helps identify slouching by measuring the amount of spinal bending. The force sensor detects excessive back strain by measuring the pressure exerted on the backrest. The MPU6050 gyroscope and accelerometer simultaneously track upper-body orientation, identifying lateral, forward, or backward leaning that goes beyond permissible posture limits.

Personalized Threshold Adjustment

The system uses a Flutter mobile application where the user enters height and weight in place of manual hardware calibration. The ESP32 receives these parameters, and, totally hands-free, it decides individual flex and force limits. This enables more accurate differentiation and reduces users configuration and flexibility false notifications.

Real-Time Evaluation and Alerting

Custom ranges are defined by users, and these ranges are subsequently evaluated by the ESP32 which continues data acquisition. Over Wi-Fi, the ESP32 sends the mobile app data and notification. The app receives sensor data and sends notifications, informing the user about posture-related problems where the user deviates by slouching, reclining too far, tilting too much, etc. To minimize unnecessary alerts caused by temporary movements like stretching or reaching, a simple time-based check was introduced. Instead of generating an alert immediately when the posture crosses the set limit, the system waits for the deviation to persist for a short period. An alert is triggered only if the improper posture continues beyond this duration. This approach helps avoid false warnings while still ensuring that the system responds quickly to genuine posture issues.

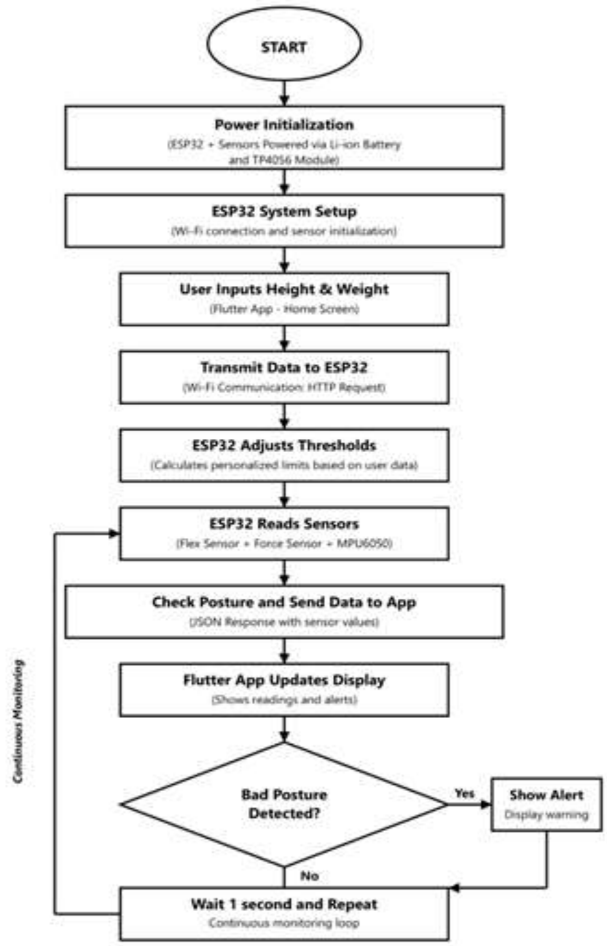

Fig.2. Flowchart of the proposed Posture Monitoring and Back Pain Alert System

The proposed system's operational flow is shown in Fig.2. Once the ESP32 is turned on and initialized and the user has entered their height and weight into the Flutter application, the ESP32 receives the information and adjusts the thresholds for the posture detection accordingly. The ESP32 looks at the posture and keeps reading the MPU6050, flex and force sensors, and sends the processed data and warning status to the application. The system performs this process repeatedly for ongoing surveillance, while the Flutter application displays data and sends an alert if bad posture is detected.

Feedback and Posture Correction

The flutter app issues real time notifications to the user to correct their posture. We see this as a way to promote healthy sitting postures and at the same time reduce the risk of long term musculoskeletal issues. Also we did away with the use of cameras and uncomfortable wearables.

V. RESULTS AND DISCUSSIONS

In implementing and evaluating the performance, sensitivity, and practicality of the Test and Evaluation of Prototype system involving various types of seating, utilization of the prototype of the Posture Monitoring and Back Pain Alert System continued. Part of the test configuration that encompassed the Flutter Mobile Application for Setting and Displaying Threshold Alerts included an ESP32 microcontroller, a flex sensor, a force sensor, and an MPU6050 IMU. By Wi-Fi Posture status was sent from the ESP32 to the mobile application, removing the need for cloud services.

Sensor Performance

The variation in spinal curvature throughout the sensor enabled the clear differentiation of slouched vs upright posture. While the force sensor exhibited all pressures recorded, slouched positions continued to show a significant increase in backrest force, as normal seating exhibited a more average force value. Beyond the thresholds of the slouch was toleranced by MPU6050 from a consistent measurement of tilt in the pitch and roll axes. The system reduced false alerts and enhanced detection consistency among users by dynamically modifying the flex and force thresholds according to user height and weight.

TABLE I. SENSOR RESPONSE UNDER DIFFERENT SITTING POSTURES

Posture Condition	Sensor Measurements			
	Flex Sensor Output	Force Sensor Output	Tilt Angle	Posture Classification
Upright Sitting	1420	1380	72.10	Normal Posture
Slight Forward Slouch	1685	1495	64.30	Moderate Posture Deviation
Severe Slouch	1895	2120	52.40	Incorrect Posture Detected
Left Lateral Lean	1580	1605	45.60	Incorrect Posture Detected
Right Lateral Lean	1605	1720	95.20	Incorrect Posture Detected

Table I shows the sensor measurements obtained for different sitting postures during system testing. The flex sensor values increase with spinal bending during slouching, while the force sensor indicates higher backrest pressure in improper sitting conditions. The MPU6050 tilt angle helps detect body leaning from the normal posture. These results demonstrate that the proposed system can effectively differentiate between normal and incorrect sitting postures.

Hardware Implementation

The hardware implementation of the posture monitoring and back pain alert system is shown in Fig.3. We have a breadboard mounted ESP32 microcontroller, a flex sensor, a force sensitive resistor (FSR) and an MPU6050 accelerometer--gyroscope module which we use to record tilt, bend and back pressure data. Power to the system is supplied by a Li ion battery which in turn is charged via a TP4056 charging module. For real time processing, threshold analysis and wireless communication with the Flutter mobile app which gives the user alerts and real time posture data we send all sensor signals to the ESP32.

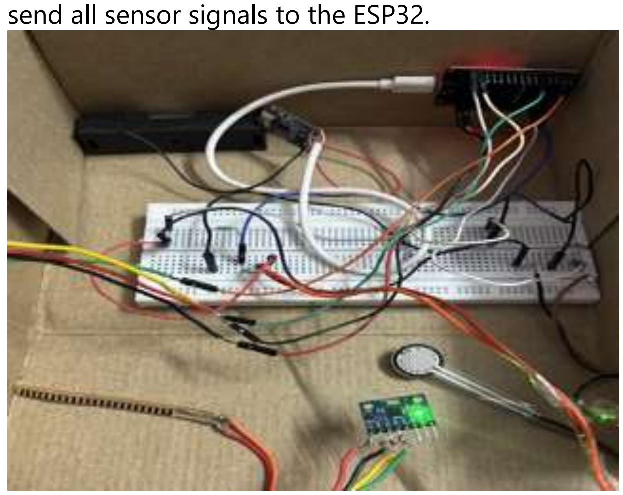

Fig.3. Hardware implementation of the proposed Posture Monitoring and Back Pain Alert System

Real-Time Monitoring

From posture deviation to alert display in the Flutter app, the system maintained a real-time processing and notification delay of less than 500 ms. Users were able to adjust their posture without any discernible lag thanks to this responsiveness. The system is appropriate for study, office, and school settings where prolonged sitting takes place because it showed stable operation during continuous monitoring over long periods of time (1–3 hours).

Beyond short-term trials, the system was also tested under regular day-to-day usage over several consecutive days to evaluate its stability, battery performance, and consistency in generating alerts. Throughout this period, the sensor readings remained stable without any noticeable drift, and the Wi-Fi connectivity was consistently reliable. These extended observations suggest that the system can operate dependably over longer durations and is suitable for practical real-world deployment.

Software Implementation

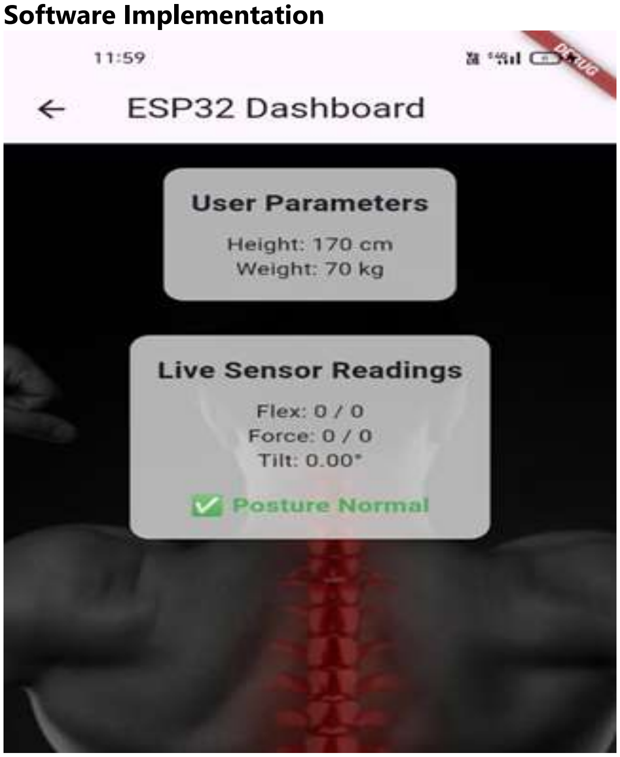

Fig.4. Software implementation of the proposed Posture Monitoring and Back Pain Alert System

Fig.4 showcases the software implementation interface that was made using the Flutter mobile application. The customized threshold computations of the ESP32 take into account the user's app-provided weight and height. The dashboard updates in real-time, displaying the tilt angle, force value, and flex value received over Wi-Fi from ESP32, and the data is in JSON. The app offers real-time feedback of the assessed posture status, and the feedback is classified into two such as "Posture Normal" and improper posture alert messages, which are notifications that the app sends when a user is sitting with bad posture. The software interface provides reasonable measures and effortless user control for monitoring posture when sitting for long periods of time.

Accuracy and Reliability

Multiple users with varying body types and seating preferences participated in the testing. The in between 90 to 93 percent we saw for the systems which identified common postures like forward lean, over extension in the back, and slouching' was doable. While it was in the acceptable performance range it did see some precision which was a step back in the case of side lean which we put down to different degrees of movement in the torso. Also we saw that the system did a better job at customizing to the individual which in turn reduced the need for manual calibration which they achieved through a feature of adaptive thresholds which used user data.

User Feedback and Usability

According to user feedback the Flutter app's visual alerts were very unobtrusive and at the same time very effective at bringing about posture correction. In shared workspaces which require privacy and which are very low in terms of tolerance for disruption, users preferred the app based alerts to audio or vibration signals. Also what was very much valued by the users was the system's battery powered design, portability, and that it didn't have wearables which made for easy and comfortable frequent use.

Discussion

When compared with existing posture monitoring solutions, the proposed system demonstrates a comparable accuracy level of around 90–93%. It also provides better personalization by adjusting thresholds based on individual user patterns. Since the design does not rely on cameras, it naturally protects user privacy and can function without continuous internet dependency. In addition, the overall implementation cost is relatively low. These features make the system particularly practical for use in classrooms and office settings, where privacy and affordability are important considerations. After studying the impact the suggested system provides in terms of mitigating the risk of posture induced back pain, the findings indicate the system provides prompt remedial feedback and continuous monitoring, which aids in mitigating the risk of back pain triggers, for posture induced pain.

Using software improves personalization and therefore customization for various body types stays feasible, and not only is there no need for hardware adjustments, but multiple sensors improve detection accuracy for system detection as opposed to single-sensor. Flexibility of the system was adjusted to lose the cloud notifying system which improves privacy and offline functionality. Minor limitations include reacting to sudden, short movements that are not related to posture, such as reaching or stretching. Posture classification and long term trend analysis to track posture habits and trends.

VI. CONCLUSION

An ESP32 microcontroller and several non-intrusive sensors in our Posture Monitoring and Back Pain Alert System are successfully incorporated for real time posture assessment and correction. We have designed the system to identify common postural issues like slouching, large amounts of back pressure, and atypical torso lean which it does so by use of flex, force, and tilt sensors. Also we were able to improve the systems' wide user base appeal which in turn removes the need for manual calibration by way of a Flutter based mobile app for height and weight tuned threshold settings. We improved convenience which at the same time protected user privacy and improved ease of use with our mobile app's which also displays real time posture report and alerts.

The system is a go for home, office and educational use which we have achieved via our compact hardware design, battery powered operation and low price. In future work, the hardware can be redesigned into a more compact form, either as a lightweight wearable device or integrated directly into a smart chair for better usability. The system can also be improved by incorporating a lightweight machine learning approach to achieve more accurate posture classification. Additionally, adding long-term posture tracking and trend analysis would help in understanding user behavior over time and provide more meaningful feedback for posture improvement.

REFERENCES

1. J. Park, S. Lee, and H. Kim, "Wearable sensor framework for posture monitoring," IEEE Sensors Journal, vol. 22, no. 12, pp. 11522–11531, 2022.
2. R. Gupta and A. Kaur, "Low-cost flex sensor-based posture monitoring system for office workers," IEEE Access, vol. 10, pp. 84512–84523, 2022.
3. M. Ahmed, T. Rahman, and F. Ali, "Integration of wearable posture sensors with correction algorithms," IEEE Internet of Things Journal, vol. 10, no. 5, pp. 4205–4214, 2023.
4. X. Zhou, L. Chen, and Y. Li, "IoT-enabled real-time posture tracking using ESP32 microcontrollers," in Proc. IEEE Global IoT Summit, pp. 512–518, 2022.
5. R. Sharma, S. Kaur, and P. Singh, "IoT-based wearable system for back-pain alerts," IEEE Access, vol. 11, pp. 101223–101233, 2023.
6. J. Banos, H. Galvez, and I. Damas, "IoT-driven monitoring frameworks for ergonomic compliance," IEEE Sensors Conference, pp. 122–127, 2022.
7. J. Lee, K. Park, and M. Cho, "Evaluation of flex and force sensors for posture detection," Sensors, vol. 22, no. 19, pp. 7451–7462, 2022.

8. S. Atalay, M. Li, and Y. Zhang, "Textile-based force sensors for ergonomic assessment," IEEE Transactions on Industrial Electronics, vol. 70, no. 4, pp. 3221–3230, 2023.
9. F. Li, J. Zhang, and K. Wang, "Tilt-angle detection using MPU6050 for posture classification," IEEE Transactions on Instrumentation and Measurement, vol. 72, pp. 1–10, 2023.
10. A. Rajesh, P. Kumar, and R. Singh, "User-weight-based calibration in posture monitoring devices," IEEE Access, vol. 10, pp. 90811–90820, 2022.
11. Y. Wang, L. Zhou, and G. Li, "Personalized posture correction using adaptive thresholding," IEEE Internet of Things Journal, vol. 10, no. 6, pp. 5550–5561, 2023.
12. S. Mukherjee, T. Das, and R. Roy, "Mobile-integrated alerting framework for posture correction," IEEE Sensors Applications Symposium, pp. 210–215, 2022.
13. V. Singh and P. Patel, "Cloud-based real-time posture notifications using wearable sensors," IEEE Access, vol. 11, pp. 87001–87012, 2023.
14. C. Chen, H. Liu, and Z. Wu, "Comprehensive review of wearable posture monitoring technologies," IEEE Reviews in Biomedical Engineering, vol. 16, pp. 100–116, 2023.