RESEARCH PAPER

Smart IoT-Based Wearable for Continuous Posture Assessment and Musculoskeletal Risk Prevention

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ABSTRACT

A lot of people are concerned about their health issues, especially poor sitting posture, which dominates among students, office workers, and people who use digital gadgets for a longer duration of time. Prolonged bad posture can lead to long-term health problems, spinal instability and musculoskeletal pain. Hence the solution for the above problem using a flex sensor coupled with an ESP32 microcontroller and Internet of Things-based input via the Blynk platform, this project suggests a non-intrusive, real-time posture monitoring system. This system continuously detects back curvature and transforms the analog fluctuations into useful posture classifications. A robust filtering and calibration process ensures that noise and individual body-structure differences are minimized. The technology remotely logs posture data to the cloud for long-term study and instantly offers feedback via LEDs and buzzer alerts based on the analysed values. When bad posture lasts longer than a predetermined amount of time, the Blynk app shows real-time readings, posture status, and alerts. The suggested model is inexpensive, comfortable to wear, and appropriate for daily usage. The device can accurately differentiate between good and bad posture, according to experimental testing, providing a useful technology intervention to encourage healthy sitting practices and avoid musculoskeletal strain.

Keyword: Wearable device,Flex sensor,ESP32 microcontroller,posture Score,Behaviour analysis.

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1. INTRODUCTION:

In today's busy world people are fully engaged with their work and not concerned about the minor health problems, which has a major impact in their future. One such issue is poor sitting posture. Sitting the the one of the major posture we follow in our life, hence if it is not proper ,then we should face the consequences for it. Postural monitoring and correction are necessary since many musculoskeletal illnesses are linked to the onset and aggravation of persistent poor spinal posture. It is a slow process and hence if we correct it in the beginning stage ,we will be able to prevent many health issues. Electronic devices or computers that can be worn on the body are referred to as wearables. Since the turn of the twenty-first century, many gadgets have decreased in size and expense while enhancing the ability to observe several health-related data, leading to a move toward commercialization and integration into routine tasks .There were 61 million wearables tracking physical activity online in 2016; by 2020, that number is expected to rise to 187 million. In the end, bad posture can result in a substantial financial burden due to higher medical expenses and decreased productivity at work [1]. The growing incidence of bad posture in the general population is driving the development of wearable technologies for postural monitoring. The musculoskeletal system can be harmed by poor posture, which can worsen chronic musculoskeletal pain, impair balance, limit functional ability, and lower quality of life. In addition to causing structural and functional harm, postural abnormalities can lead to joint loading and muscular strain. In addition to altering self-esteem and body image, posture can cause hormonal and emotional changes that have an impact on psychological well-being. There are two types of spinal changes: structural and non-structural. Morphological abnormalities of soft tissues or bones cause structural changes, which usually demand for the usage of mechanical feedback devices since they need structural support. Non-structural changes, such as compensatory and perhaps changeable postural patterns, tend to rely on devices that deliver vibratory feedback, thereby promoting active self-correction.[2] Growing, working, and elderly populations are among those who may experience spinal diseases. For example, the most prevalent type of idiopathic scoliosis, accounting for around 80% of cases, is teenage scoliosis. The lifetime prevalence of low back pain ranges from 65% to 80%, and it is always a significant burden on society due to the high expenses associated with health care consumption, work absenteeism, and disability. Low back discomfort is associated with occupational exposures in working populations, including heavy and/or repetitive lifting, fixed postures, and prolonged sitting, especially in incorrect postures. In the general population, 25% of women over 50 have one or more vertebral fractures, which cause height loss and increased kyphosis.[3].IT professionals have a frequency of 67%, students have a prevalence of 37.1%, and laundry personnel have a prevalence of 28%, among many other professionals who operate in a slouched position for extended periods . This syndrome affects 11% to 60% of persons across different societies and ages .Delays in therapy can lead to secondary issues such as impingement syndrome, cervicogenic headaches, shoulder instability, poor joint position sensing, and decreased maximum ventilation. Upper cross syndrome symptoms include pain, decreased physical function, and the possibility of long-term absences from work. This can cause significant economic hardship on society [4].

Posture correction in physiotherapy and ergonomics aims to restore biomechanical alignment, minimize tissue loading, and enhance functional capability and quality of life. For decades, physicians have used traditional postural assessment procedures like visual inspection, plumb lines, goniometers, and radiography. Traditional procedures do not provide constant, objective, and real-time corrective feedback, which is essential for motor relearning and long-term behaviour change. Conventional interventions lack precision, scalability, and interactivity, highlighting the need for more advanced solutions [5]. People began to adopt a sedentary lifestyle. On average, these individuals are thought to spend over half of their daily hours sitting down; in the case of those with limited mobility, this number may reach 85%. Bone and muscle are closely associated with the reason of this sedentary lifestyle. People with limited mobility must utilize an assistive equipment, like a wheelchair, to enable them to move around properly as a result of this muscle weakening. Although using a wheelchair increases a person's mobility and, thus, their level of freedom, its use is linked to an increase in sitting posture and the related psychological and physical issues. The application of an intelligent postural diagnosis system is thought to be advantageous for the early avoidance of changes in users' functional status, allowing therapy to be tailored to each user and pathology. [6]. The contraction of skeletal muscle groups that guarantee a specific position of the body and its components in space determines an individual's "habitual attitude," or posture. These days, clinical approaches range from instrument-assisted techniques like plumb line assessment and scoliometer measures to observational techniques like standing posture assessment and the Adams forward bend test. For a conclusive diagnosis, radiographic imaging—especially standing x-rays with Cobb angle measurement—remains the gold standard. Improving postural control, limiting curve advancement, and delaying or avoiding invasive procedures are the main goals of preventive and conservative methods. Teenagers with postural abnormalities may benefit from physiotherapy techniques like Global Postural Re-education (GPR), which emphasizes respiratory regulation, postural alignment, and muscle chain rebalancing [7].The average age of the population has been rising in recent years, particularly in developed nations. According to recent European Union (EU) statistics, the proportion of the population that is 65 years of age or older is predicted to rise from 20.8% in 2021 to 31.3% in 2100. Due to the quick development of specially designed sensor systems, health has become more significant in recent years. Examining an individual's everyday activities is crucial to comprehending their lifestyle. Posture is based on how the skeleton and muscles are positioned throughout different daily activities. Postural analysis is crucial for identifying bad postural patterns that lead to a number of issues, including scoliosis, shoulder pain, back pain, and more, in addition to keeping an eye on people's activities [8].In the workplace, flexed head and neck positions are linked to the emergence of neck pain. The purpose of this study was to assess how the wearable posture sensor affected the head and neck's posture and physical demands while working in an office. Compared to participants without the wearable sensor, those with it had, on average, 8% lower neck flexion angles and 14% lower neck gravitational moments. When using the standing workstation as opposed to the sitting workstation, the wearable sensor had a greater impact on lowering neck postural stress. In an office situation, the wearable posture sensor may be a useful tool for reducing neck postural stress [9].A new posture correcting system was created. The technique was designed to stop undesirable postures from developing unintentionally. The three subsystems that make up the newly created system are a smartphone, notebook computer, and smart necklace. The notebook computer is able to use a depth camera to read pertinent data, identify the user's skeletal structure and joint reference points, and compute calculations related to those reference points. The computer then transmits signals to the smart necklace so that the standard values of the smart necklace can be calibrated. A smartphone app that was also created as part of the study enables the smart necklace to send reminders to the user's smartphone when it detects bad posture[10].

From the above discussion we can conclude that the wearable correction device can surely detect poor posture detection and also correct it,which ultimately leads to improved spinal related problems.

2. LITERATURE SURVEY:

In this study, **Morufu Olusola Ibitoye et al. (2022)** developed a low-cost and user-friendly posture monitoring device aimed at detecting abnormal spine alignment and musculoskeletal issues using a single flex sensor. The authors highlighted the growing prevalence of musculoskeletal disorders caused by poor posture during daily activities such as sitting and standing. Their system utilizes a resistive flex sensor placed on the upper back region to detect bending or slouching by measuring changes in resistance. An Arduino Uno microcontroller processes these signals and activates a buzzer to alert the user whenever poor posture is detected. The device is designed to be wearable, portable, and suitable for real-time monitoring without requiring complex infrastructure. Unlike earlier approaches that rely on expensive motion capture systems or multiple sensors, this design focuses on simplicity and affordability. The study also incorporated a calibration mechanism to establish a baseline posture for accurate detection. Experimental validation on human participants demonstrated that the system could effectively identify posture deviations across different angles. The reported sensitivity of approximately 84.6% indicates reliable performance for practical applications. Furthermore, the device was found to be particularly beneficial for individuals in low-resource settings and occupations involving prolonged static postures. Overall, the work contributes to the development of accessible healthcare monitoring solutions with potential for preventing long-term musculoskeletal complications [11]. **T. Kavitha, Nama Aakash, Karamtoth Kishore Kumar, and Abbavaram Rushikesh Reddy** (2023),present a wearable posture monitoring system that integrates flex and accelerometer sensors to identify improper body alignment. The authors focus on detecting spinal curvature using a flex sensor while simultaneously analyzing neck inclination through an accelerometer, enabling a more comprehensive posture evaluation. Unlike earlier approaches that relied on a single sensing parameter, this dual-sensor method improves accuracy in distinguishing between correct and incorrect postures. The system employs an ESP32 microcontroller to process real-time sensor data and trigger a buzzer alert whenever abnormal posture is detected. Additionally, the study incorporates cloud connectivity, allowing continuous storage and remote monitoring of posture data. A mobile application interface is also introduced to visualize posture metrics and provide user feedback. The authors highlight the limitations of existing systems, such as high cost, lack of portability, and reliance on complex image processing techniques. By proposing a compact and cost-effective solution, the study aims to promote daily posture awareness without restricting user movement. The results demonstrate clear differentiation between normal and abnormal posture ranges based on sensor outputs. Overall, the work contributes to the development of accessible wearable health monitoring systems with real-time feedback and long-term data analysis capabilities [12].In this study Swapnali Dhulap (2021) along with co-authors proposes an IoT-based smart wearable system aimed at detecting and correcting poor posture in real time. The work emphasizes the growing prevalence of lower back pain due to improper posture and highlights the need for continuous monitoring solutions. The authors design a wearable device integrating a NodeMCU microcontroller, an IMU (MPU6050), and a flex sensor to capture spinal movement and angular orientation. Their system establishes a reference posture during an initial calibration phase and continuously compares real-time data against this baseline. When deviations beyond a threshold are detected, the system triggers alerts through vibration and mobile notifications. The inclusion of wireless communication enables users to monitor posture data remotely, enhancing usability and accessibility. The study also addresses limitations in existing posture correction devices, particularly their lack of real-time feedback and accuracy. By combining multiple sensors, the proposed system improves detection reliability and responsiveness. Experimental results based on tri-axial measurements demonstrate the system's capability to differentiate between correct and incorrect postures. Overall, the paper presents a cost-effective and practical solution that leverages IoT technology to promote healthier posture habits and reduce long-term musculoskeletal issues [13].

In this study, **Jorge E. Caviedes, Baoxin Li, and Varun C. Jammula** (2020) proposed a novel wearable sensor-based system for monitoring spinal posture during therapeutic exercises. The authors focused on addressing the major challenge of evaluating correctness and compliance in home-based physical therapy programs. They introduced a lightweight triangular stretch sensor array integrated into a garment or harness to measure changes in distances across the shoulders and lower back. The collected sensor data is transmitted wirelessly and analyzed using a pattern recognition algorithm to identify whether exercises are performed correctly.The study emphasizes the use of a low-dimensional classification approach instead of complex machine learning models, making the system efficient and practical for real-time applications. Experimental validation was conducted through simulated data, scoliosis therapy exercises, and multiple lower back flexibility routines performed by different subjects. The results demonstrated high specificity (100%) and sensitivity ranging from 70% to 100%, indicating reliable detection of correct and incorrect exercise execution.Furthermore, the authors incorporated a mobile application to provide real-time biofeedback, enhancing user engagement and adherence to therapy routines. The research highlights the importance of simplifying wearable sensor design while maintaining accuracy, and it presents a scalable solution for personalized rehabilitation monitoring. Overall, the study contributes a practical and cost-effective approach to improving home-based physical therapy outcomes through wearable technology and intelligent signal processing [14].

Alvaro Rodriguez and co-authors (2021) present a wearable postural control system aimed at reducing low back pain through real-time monitoring and feedback. The authors emphasize that improper posture is a major contributor to musculoskeletal disorders, particularly low back pain, which affects a large portion of the population. To address this, they designed a low-cost wearable device integrating multiple inertial measurement units (IMUs) placed along different sections of the spine. These sensors combine accelerometers, gyroscopes, and magnetometers to accurately estimate spinal orientation and movement.The study introduces a novel approach by combining posture detection with a fuzzy logic-based feedback mechanism that activates vibration alerts when incorrect posture is sustained. Unlike traditional systems, the proposed device focuses on both absolute and relative orientation of spinal segments, improving accuracy in detecting complex spinal curvatures. The authors validated the system through static and dynamic experiments, achieving high accuracy with minimal error. Furthermore, a pilot clinical study involving patients demonstrated improvements in postural awareness and a reduction in reported pain levels.The research highlights the importance of personalized therapy, where clinicians can set baseline posture and acceptable deviation limits for each individual. Compared to existing commercial solutions, the proposed system is significantly more affordable while maintaining comparable or better performance. Overall, this work contributes to the advancement of wearable healthcare technology by integrating sensing, real-time processing, and intelligent feedback for effective postural rehabilitation [15].In this study, Rik Bootsman and Panos Markopoul (2019) explore the role of smart garments in preventing occupational low back pain through continuous posture monitoring. The authors highlight that prolonged and repetitive awkward postures, especially among nurses, significantly contribute to musculoskeletal disorders. To address this, they introduce "BackUp," a wearable system integrating textile-based sensors with a smartphone application to provide real-time feedback on lumbar posture. The study emphasizes the importance of accurate sensor placement, achieved through anthropometric analysis, to ensure reliable posture detection. Unlike conventional wearable devices, the proposed smart shirt focuses specifically on lumbar curvature rather than general body inclination, improving feedback precision.Furthermore, the authors investigate user experience through field studies, revealing that wearable feedback can increase awareness of poor posture, although long-term behavioral change requires further validation. The research also discusses challenges such as user compliance, notification fatigue, and the need for personalized feedback mechanisms. By combining sensing technology with persuasive feedback strategies, the study demonstrates the potential of interactive clothing in workplace health monitoring. Overall, this work contributes to the growing field of wearable healthcare systems by presenting a practical and user-centered approach to posture correction in real-life conditions [16].In this study, **Katharina Stollenwerk, Jonas Müller, André Hinkenjann, and Björn Krüger (2019)** investigate spinal shape changes during posture training using a wearable sensing system. The authors focus on addressing the widespread issue of lower back pain by leveraging real-time posture feedback through wearable technology. They utilize the Gokhale SpineTracker™, a multi-sensor accelerometer-based device, to capture detailed spinal curvature data in different positions such as standing, sitting, and hip hinging. The study emphasizes the use of real-world posture data rather than relying on predefined "normal" spine models, which distinguishes it from many traditional approaches.The researchers extract geometric features from paired snapshots of unguided and guided postures to analyze how posture improves with training. They apply dimensionality reduction techniques like Principal Component Analysis (PCA) and t-SNE to transform high-dimensional posture data into a meaningful low-dimensional representation. Further, clustering is performed using minimum spanning tree (MST) methods to group similar posture changes. The results demonstrate that these clusters correspond to meaningful patterns in posture correction, as validated by a professional posture trainer.Overall, the study highlights the effectiveness of combining wearable sensors with data-driven analysis to understand posture improvements. It also shows that individualized posture assessment, without relying on generalized standards, can provide valuable insights for rehabilit[\ation and training. This work contributes to the advancement of wearable health technologies and opens possibilities for personalized posture correction systems [17].**Cortell-Tormo, García-Jaén, Ruiz-Fernández, and Fuster-Lloret [2019]** present the development of a wearable system called Lumbatex for monitoring lumbar spine curvature and motion. The authors emphasize the growing prevalence of low back pain and highlight the need for accurate, objective, and real-time monitoring methods in rehabilitation and sports settings. They propose a smart textile-based device integrated with inertial sensors, including accelerometers and gyroscopes, to capture spinal movements across multiple planes. Unlike traditional clinical methods that rely on manual assessment or limited-dimensional measurements, this system provides continuous quantitative feedback on spinal posture.The study details both hardware and software components, where sensor data is transmitted via Bluetooth and visualized through user-friendly interfaces. The system is validated through static and dynamic testing, demonstrating high accuracy with minimal error in curvature measurement. Additionally, user-based evaluations indicate that the device is comfortable and suitable for prolonged use. The authors also compare their system with existing technologies, noting improvements in portability, cost-effectiveness, and real-life applicability.Overall, the research contributes to the advancement of wearable rehabilitation technologies by offering a practical solution for monitoring lumbar spine alignment and movement. The system shows strong potential for applications in clinical therapy, ergonomic assessment, and preventive healthcare [18].In this study, **Krutika Bramhapurikar, Arohi Prabhune, Snehal Chavan, Girish Chandra Ghivela, and Joydeep Sengupta** present a wearable posture correction device aimed at reducing back pain caused by poor posture. The authors focus on designing a low-cost and user-friendly system that can be easily integrated into daily life. Their work emphasizes the use of a flex sensor to detect spinal bending, which serves as the primary sensing mechanism. The study highlights the importance of accurate sensor placement, identifying the lower back region as optimal for consistent posture detection. A microcontroller-based system processes the sensor data and determines whether the posture is correct or incorrect through a calibrated threshold mechanism.The authors incorporate a feedback system that includes both a vibration motor and Bluetooth communication to alert users in real time. This dual-alert approach ensures accessibility for users with different sensory preferences. The integration of a low-noise amplifier enhances the sensitivity of the sensing system, enabling detection of slight posture deviations. Additionally, the use of a graphical display improves user interaction during calibration and operation. The study demonstrates that personalized calibration makes the device adaptable to different individuals. Overall, the paper contributes to the development of simple, effective, and affordable wearable health monitoring solutions, particularly for posture correction in sedentary lifestyles [19].In this study, **Pedro Ribeiro, Ana Rita Soares, Rafael Girão, Miguel Neto, and Susana Cardoso(205)** present a novel wearable system called Spine Cop aimed at real-time posture monitoring and correction. The work focuses on addressing common spinal issues caused by poor daily posture through a compact and non-invasive device. The authors integrate multiple sensors, including accelerometers, gyroscopes, and magnetometers, along with strategically placed permanent magnets to enhance posture detection accuracy. Unlike traditional systems that rely on a single sensing modality, this study emphasizes sensor fusion to capture both spinal inclination and shoulder blade movement. A probabilistic classification algorithm is introduced, where user-specific calibration data are modeled using Gaussian distributions to distinguish between correct and incorrect posture. The system determines posture quality based on confidence regions derived from statistical thresholds, improving adaptability across individuals. The inclusion of magnetometer data significantly enhances performance, particularly in distinguishing correct posture during body tilting scenarios. Experimental validation demonstrates that combining magnetometer and accelerometer data achieves higher accuracy compared to using accelerometer data alone. The device also provides a posture score, enabling long-term monitoring and user awareness. Overall, the study contributes an efficient, low-cost, and user-friendly solution for continuous posture assessment in both clinical and everyday environments [20].

3.Materials and Methodology

3.1.COMPONENTS USED:

3.1.1 ESP32 microcontroller

The ESP32 is chosen for its built-in Wi-Fi connectivity, dual-core processor, low-power modes, and high-resolution ADC inputs that enables both analog and digital sensors user -friendly. When compared to Arduino Uno or Nano, the choice of ESP32 is supported by its superior computational capability making it appropriate for both sensor data processing and IoT tasks without the need for external communication modules. Furthermore, ESP32 provides ample memory space for filtering algorithms, data logging, and complex calibration programs.

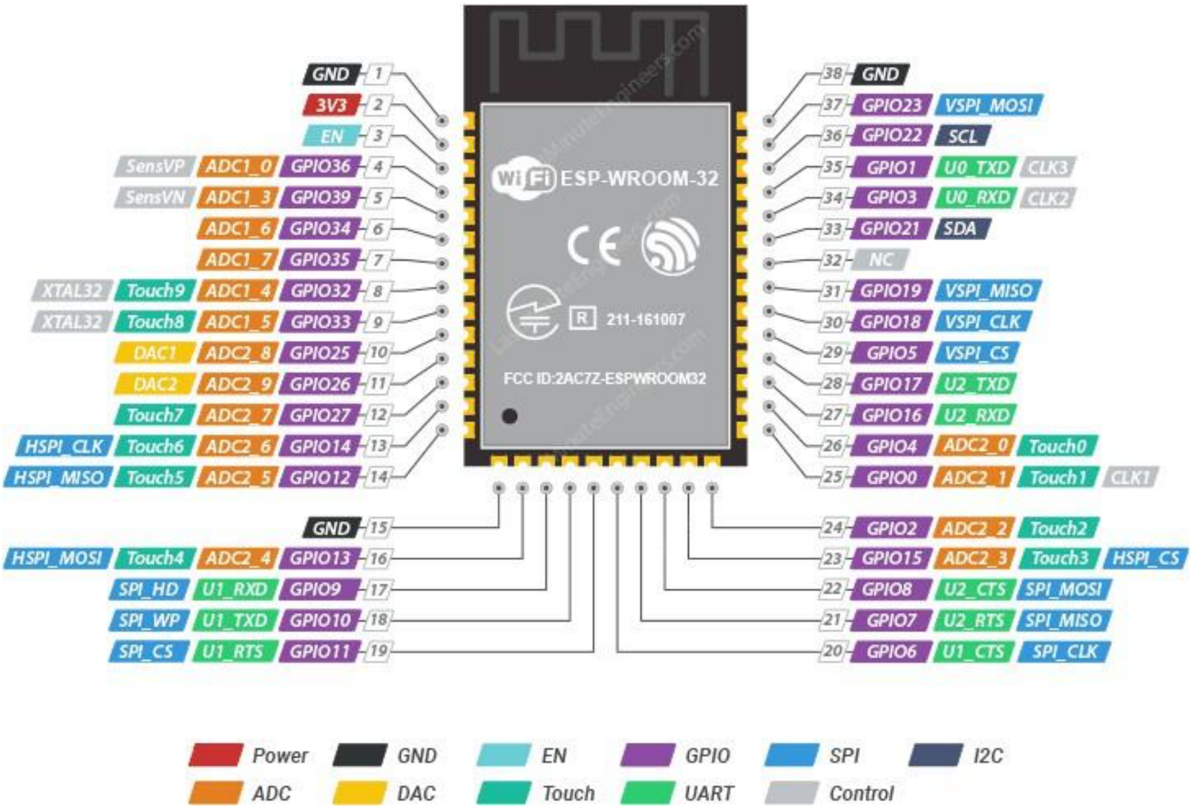

Figure 1 ESP32 WROOM Development Board

3.1.2. Flex Sensor:

The flex sensor was chosen as the principal sensor due to its lightweight design, mechanical flexibility, and ability to create a predictable change in electrical resistance when bent. This feature makes it excellent for detecting the curvature of the spine when the user slouches. While IMUs (Inertial Measurement Units) are an option, they suffer from continual drift over extended sessions and complicate orientation estimation. For this phase of the project, the flex sensor has shown to be a simpler and more sustainable method to long-term, real-world posture detection.

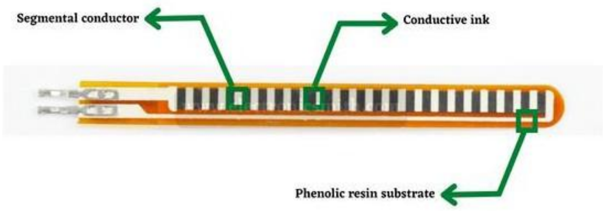

Figure.2 Flex sensor

3.2. Existing System

Physiotherapy, ergonomic modifications, and manual observation are examples of traditional posture correction techniques that have a number of drawbacks. These approaches are frequently reactive rather than preventive, which means they deal with issues after they arise rather than stopping them before they start. They also call for consistent work, self-control, and occasionally expert supervision, all of which might not be possible for everyone. Medical research regularly shows that longer exposure to bad posture is a primary cause of spinal discomfort, muscle fatigue, disc compression, and postural deformities. The solutions for such as continuous posture monitoring, have been demonstrated to reduce musculoskeletal strain and improve posture-related health problems. To detect the position and angular orientation of the spine, conventional posture correction systems usually use either physical sensors like flex sensors and pressure sensors or inertial sensors like accelerometers, gyroscopes, and magnetometers. These sensors monitor bending angles, continuously gather data on body movements, and detect departures from a calibrated "ideal posture." Vibrations, an audio buzzer, LED indications, or alerts sent via a linked smartphone app can all be used to convey feedback, The current drawbacks are not exact accuracy obtained, misunderstanding of movements ,comfortable issues and only few parameters are determined.

3.3. PROPOSED SYSTEM

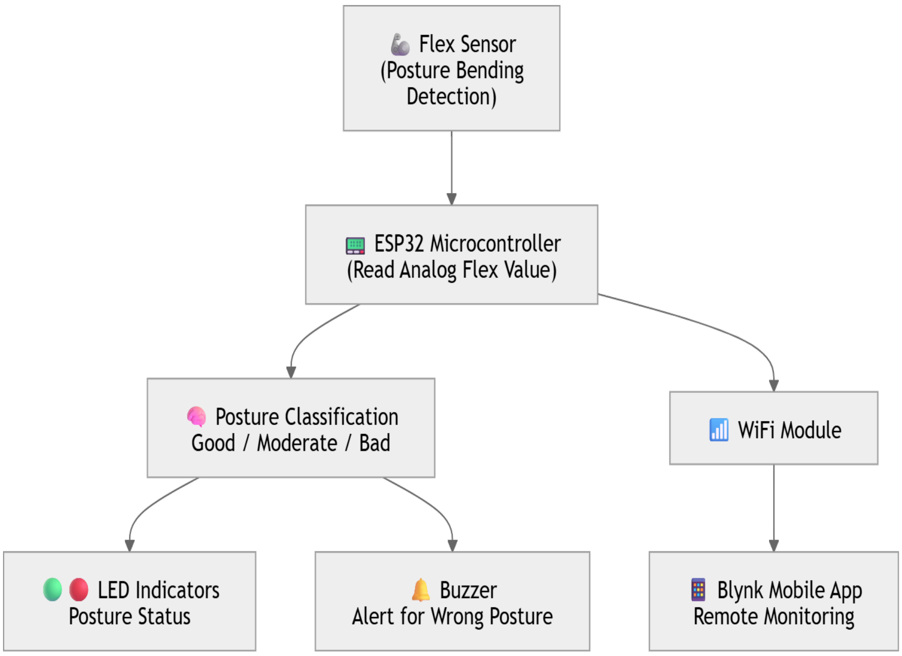

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Figure 3 Block diagram of the proposed system

The suggested system uses a flow of sensing, processing, classification, and feedback to function as a real-time posture monitoring and alarm system. The main sensing element in charge of identifying changes in posture is the flex sensor. When the user strays from an upright position, the sensor, which is positioned along their upper back, bends. The resistance of the sensor varies as a result of this bending, and this change is directly correlated with the curvature of the spine. The sensor maintains a constant resistance value and stays generally straight when the posture is correct. In order to detect posture, this bodily shift is transformed into an electrical signal.The ESP32 microcontroller receives the analog signal produced by the flex sensor.The ESP32's integrated analog-to-digital converter (ADC) reads the analog voltage that corresponds to the resistance of the sensor.. In order to guarantee that posture is tracked in real time without any delays, the microcontroller constantly samples this information at regular intervals. The ESP32 uses simple filtering techniques to smooth the data because sensor readings contain noise and slight oscillations brought on by modest body motions or environmental influences. This guarantees that only significant variations in posture are taken into account for additional processing.After the data has been stabilized and filtered, it moves on to the classification stage, where the algorithm assesses the user's position.During the calibration stage, predetermined threshold values are established for the classification process. Three categories of posture are distinguished by these thresholds: good, middling, and terrible. The posture is deemed good when the sensor results are within the permitted range, signifying that the user is keeping their spinal alignment correct. The posture is classified as moderate if the values show a little variation that could need to be corrected. However, the posture is deemed poor if the sensor readings are higher than the specified limitations, indicating severe slouching or improper alignment. The system alerts the user by activating suitable feedback mechanisms based on the identified posture condition. LED indicators provide visual feedback; a green LED denotes proper posture, a yellow LED represent moderate posture, and a red LED signals bad posture. There is a buzzer-based aural alarm system. The buzzer is activated to give instant feedback when the device identifies poor posture. Because it reminds the user to immediately modify their posture and avoids chronic strain on the spine, this alarm mechanism is especially useful. With its built-in Wi-Fi functionality, the ESP32 manages wireless communication in addition to the local feedback system.The Blynk IoT platform is used to provide the processed posture data to a mobile application. Beyond instant alerts, this wireless connectivity improves the system's functionality and permits remote monitoring. Real-time posture data is shown in the Blynk mobile application's user-friendly interface as graphs, indications, or status alerts. Data logging and historical analysis are also made possible via the interface with the Blynk platform. Users can monitor their posture habits and spot trends thanks to the system's long-term recording of posture data. Users can identify times of the day when they frequently have bad posture and adjust their behavior accordingly. Because it makes users more conscious of their posture habits and promotes regular correction, this long-term analysis is essential to behavioral change. Sensing, categorization, and feedback all happen nearly instantly. Effective posture correction requires this real-time responsiveness because delayed feedback may lessen the benefit of remedial measures. The system's uninterrupted operation ensures that the user's everyday activities are consistently monitored. Because of the ESP32's low-power characteristics and improved operation, the system uses less energy and can function on battery power for longer. Because frequent charging might make wearable technology less useful, this is especially crucial for user convenience. The system's lightweight and small design further improves its usability by guaranteeing that users can wear it for extended periods of time without experiencing any pain.The system is adaptable and has the potential to incorporate more features in the future in addition to its fundamental capabilities.

4.Result and Discussion:

An ESP32 microcontroller interfaced with a flex sensor, visual indicators, an audio alert, and an Internet of Things-based monitoring interface via the Blynk platform was used to implement the posture monitoring system created in this study. The system was created to assess long-term posture behavior, provide instantaneous remedial feedback, classify posture quality in real time, and continuously monitor user posture. The system operated steadily and dependably under typical usage circumstances, according to experimental evaluation.

The ESP32's 12-bit analog-to-digital converter was able to precisely record changes in sensor resistance since the flex sensor was set up in a voltage divider configuration with a 10 kΩ resistor and supplied with 3.3 V. Changes in posture were clearly and consistently correlated with the observed ADC values. Lower ADC readings suggest that the user maintained an upright posture; intermediate values were recorded after modest bending; and much larger readings occurred during poor posture. Using experimentally determined threshold values, the system correctly classified posture into good, normal, and terrible states. These thresholds produced consistent categorization results under continuous monitoring, with posture status updated at one-second intervals.

Good and normal postures engaged the green LED and displayed encouraging messages, whilst poor posture triggered the red LED and an audio buzzer, requiring urgent posture correction. This multimodal feedback guaranteed that users received timely and intuitive cues, which increased postural awareness.

In addition to rapid posture detection, the system computed a posture score to quantify posture quality over time. The posture score was calculated as the ratio of time spent in good and normal postures relative to total monitoring time. Experiments revealed that users who maintained good posture for longer periods of time had higher posture ratings, whereas frequent slouching resulted in a significant fall in score. This metric provides a simple yet effective numerical representation of total posture discipline, making long-term posture evaluation more important than instantaneous changes alone.

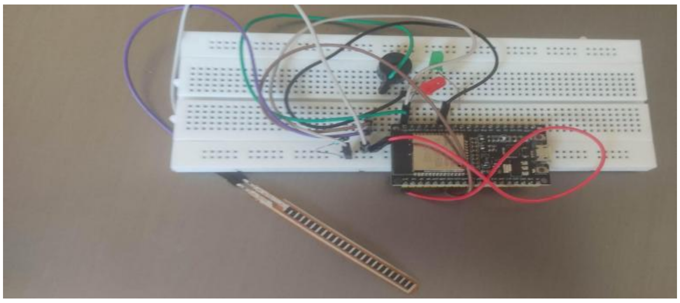


Figure 4 Hardware setup of the wearable device

As discussed earlier the fig 4 shows hardware setup consisting of ESP32, Flex sensor, LEDs and buzzer. The flex will be placed in the perfect position at spine and based on the movement, the posture will be detected. The various parameters that will be displayed on serial monitor are flex value, posture score and behaviour analysis.

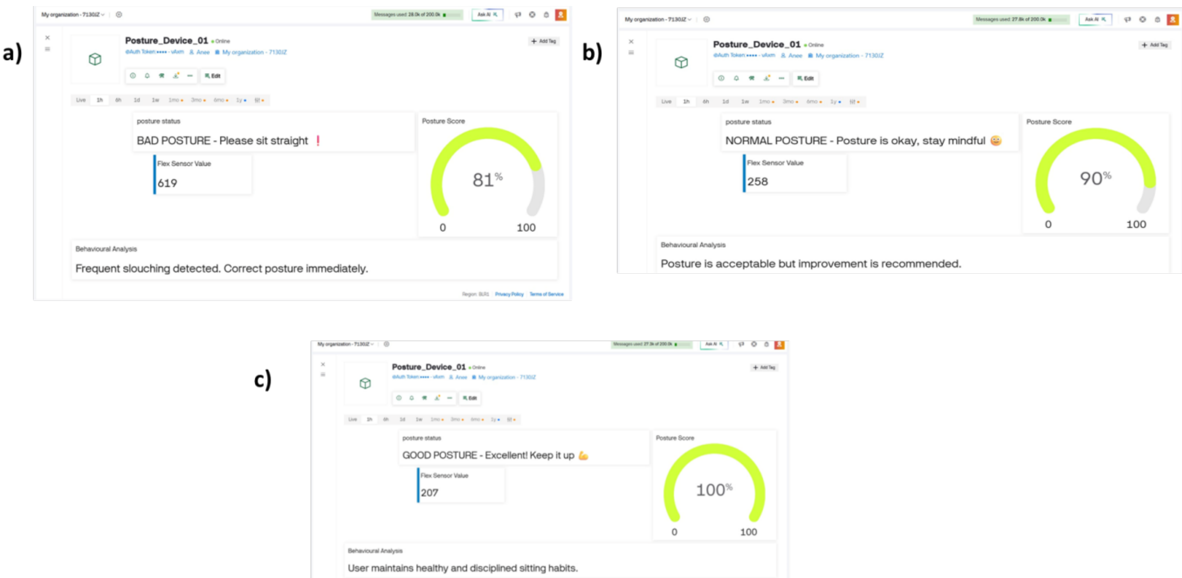


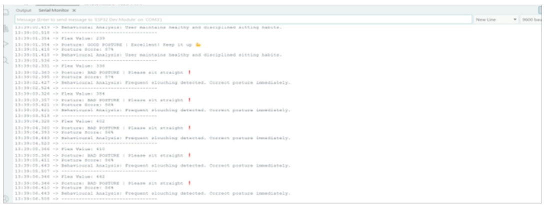
Figure 5: Represents the bad, normal and good posture detection,posture score and behaviour analysis

Figure 5 represents the various posture detected by the wearable devices with the behaviour analysis of the system. Fig 5 a) represents flex value of 619 and posture score of 81, which indicates a bad posture and user should change the position immediately, will be shown by red

LED with a buzzer sound. Fig 5b),represents flex value of 258 with posture score of 90,which indicates a normal posture ,slightly might be improved Finally 5c) represents flex value of 207 with posture score of 100 ,indicating good posture and shown by green LED.

The Blynk received real-time posture data, including flex sensor values, posture status with motivational messages, posture score, and behavioural analysis findings.IoT dashboard. While the web dashboard needed push-based settings to properly render string data, the mobile application accurately displayed all parameters in real time. Overall, the experimental findings support the suggested posture monitoring system's capacity for accurate posture categorization, dependable real-time operation, and significant long-term behavioral evaluation. The technology provides an affordable, scalable, and easy-to-use way to monitor posture in both personal and professional settings. It is appropriate for posture awareness research, ergonomic monitoring, and preventive healthcare applications because of its modular design, which makes calibration simple for various users

a)



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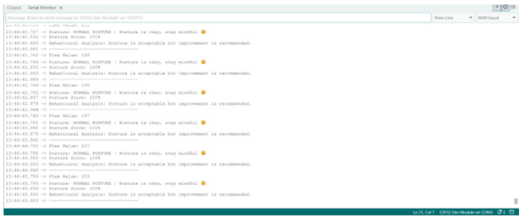

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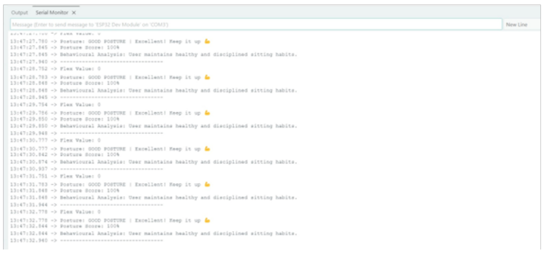

Figure 6:The Blynk message for various posture is detected

Figure 6 indicates the Blynk message for various posture detection .Fig 6 a). shows flex value above 250 which indicates bad posture and its posture score will be less than 90 ,with behaviour analysis of "Frequent sloughing is detected and correct the position immediately. ".Similarly 6 b). shows flex value below 250 indicates normal posture and its posture score will be above 90,with behaviour analysis of "Acceptable position and improvement needed". Finally 6 c).show flex value 0 indicating good posture and posture score will always be 100 ,with behaviour analysis "User maintains healthy and discipline sitting habits".

5.CONCLUSION:

The wearable posture correction tool created for this research effectively shows how to monitor spinal alignment and encourage better posture practices at a reasonable cost. Through precise analog sensing and a reliable signal-processing pipeline, the system provides real-time spine bending detection by integrating a flex sensor with the ESP32 microcontroller. Long-term periods of poor posture are avoided because to the combination of LED and buzzer feedback, which guarantees that users receive prompt remedial indications whenever a slouched position is identified. The unique finding of this work is the behaviour analysis of the person with long term analysis . Furthermore, the system is improved by the integration of Blynk IoT cloud connectivity, which enables long-term data visualization, live monitoring, and smartphone notifications—all of which together offer a full behavioural awareness tool.

The experiment results verify the device's dependability, responsiveness, and convenience of use. Volunteers reported enhanced posture awareness after only a short period of use, confirming the system's effectiveness as both correction assistance and a long-term posture improvement mechanism. The flex sensor proved to be an appropriate choice for detecting spinal curvature changes, whilst the ESP32 provided the required computing and wireless communication capabilities in a compact and power-efficient package. Overall, the initiative is successful in reaching its core purpose of developing a wearable posture correction device that is lightweight, cost-effective, and user-friendly, with applications in school, business, and the home

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