

# Posture Monitoring System: An IoT-Based Slouching Duration and Body Position Detector

## Sistem Pemantauan Postur: Pendeteksi Durasi Bungkuk dan Postur Tubuh Berbasis IoT

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**ABSTRACT** — The main risk factors for non-communicable diseases (NCDs), particularly low back pain (LBP), which affects 18.1% of the population in Indonesia, are prolonged sitting and lack of physical activity. The aim of this study was to develop an Internet of Things (IoT)-based system that can detect sitting duration and body posture to help people maintain ergonomic posture and regulate their sitting time. This system uses an ESP32 microcontroller with a flex sensor and HY-SRF05 ultrasonic sensor to identify the user's presence. To enable remote monitoring via a web application, sensor data is displayed on an I2C LCD and sent to a Firebase real-time database. A buzzer provides a warning when a person bends over (angle greater than 32.7°) or sits for longer than the set time. Test results show that the system can accurately distinguish between normal posture (9°-15°) and slouching (32°-80°). The ultrasonic system records and stores data history in real-time via Firebase, enabling analysis of user posture trends and sitting duration. The sensor accuracy rate is 98.63% with an average error of 1.37%. By adding historical data monitoring, smartphone notifications, and cloud-based data logger features, this system shows significant improvement over previous tools, although the timer test had an average time of 820 seconds. Further development is recommended to improve timer accuracy and user convenience by adding a wireless belt and a separate RTC module.

**KEYWORDS** — ESP32, Firebase, IoT, lower back pain, sedentary reminder, sitting position, posture, flex sensor

**INTISARI** — Faktor risiko utama penyakit tidak menular (PTM), terutama nyeri punggung bawah (NPB), yang mencapai 18,1% di Indonesia, adalah kebiasaan duduk terlalu lama dan kurang aktivitas fisik. Tujuan penelitian ini adalah untuk membuat sistem berbasis Internet of Things (IoT) yang dapat mendeteksi lama waktu duduk dan posisi kebungkukan tubuh untuk membantu orang menjaga postur ergonomis dan mengatur durasi duduk mereka. Sistem ini menggunakan mikrokontroler ESP32 dengan sensor flex dan sensor ultrasonik HY-SRF05 untuk mengidentifikasi keberadaan pengguna. Untuk memungkinkan pemantauan jarak jauh melalui aplikasi web, data sensor ditampilkan pada LCD I2C dan dikirim ke *database realtime* Firebase. Buzzer memberikan peringatan ketika orang membungkuk (sudut lebih dari 32,7°) atau duduk selama lebih dari waktu yang ditetapkan. Hasil tes menunjukkan bahwa sistem dapat dengan akurat membedakan postur normal (9°-15°) dan bungkuk (32°-80°). Sistem ultrasonik mencatat dan menyimpan riwayat data secara *real-time* melalui Firebase, memungkinkan analisis tren postur dan durasi duduk pengguna. Tingkat akurasi sensor 98,63% dengan *error* rata-rata 1,37%. Dengan menambahkan fitur pemantauan data historis, notifikasi *smartphone*, dan data logger berbasis *cloud*, sistem ini menunjukkan peningkatan yang signifikan dibandingkan alat sebelumnya, meskipun pengujian timer memiliki waktu rata-rata 820 detik. Disarankan pengembangan tambahan untuk meningkatkan akurasi timer dan kemudahan pengguna dengan menambahkan sabuk nirkabel dan modul RTC terpisah.

**KATA KUNCI** — ESP32, Firebase, IoT, nyeri punggung bawah, pengingat duduk, posisi duduk, postur tubuh, sensor flex

### I. INTRODUCTION

The World Health Organisation (WHO) defines physical activity as any form of bodily movement produced by skeletal muscles that requires energy. This includes a wide range of movements, whether during leisure time, when travelling to or from a place, or when performing work or household tasks. Moderate to vigorous physical activity has been proven to be beneficial to health. Some common ways to stay active include walking, cycling, exercising, engaging in recreational activities that involve active movement, and playing. These activities can be done by anyone, regardless of ability level, and can be enjoyed by all groups.

Physical activity plays an important role in supporting overall health and well-being. Conversely, a lack of physical activity or a sedentary lifestyle can increase the risk of non-communicable diseases (NCDs) and other negative health effects. A lack of physical activity and sedentary habits over a long period of time are major factors contributing to the increasing prevalence of NCDs and placing additional pressure on healthcare systems [1].

An example of this is sitting for too long while working. Sitting for too long often leads to a problematic condition known as low back pain (LBP). According to a study conducted by the American Chiropractic Association (ACA), approximately 80% of people worldwide will experience back pain at some point in their lives; the main causes are poor posture and sitting for too long [2].

In Indonesia, the prevalence of lower back pain (LBP) is not yet known with certainty. However, the results of a study conducted by the Indonesian Neurological Association (PERDOSSI) in 14 cities showed that around 18.1% of respondents experienced LBP. In Jakarta, the prevalence rate was recorded at 50.4%. The majority of sufferers are in the 50 to 60 age range, accounting for 23.7%, and around 51.9% of LBP cases occur suddenly. Therefore, a solution is needed that can help users maintain good posture and control their sitting time automatically [3].

The recommended duration of sitting without a break is a maximum of 30 to 60 minutes, after which a person is advised to stand up or stretch for a few minutes to keep blood circulation flowing and muscles from becoming tense. If a person sits for more than 1 hour without a break, the risk of muscle tension and back pain increases significantly [4], [5], [6], [7], [8], [9], [10], [11]. Therefore, this detection system is designed to provide a warning every 60 minutes of continuous sitting. In addition, based on the results of testing the flex sensor used in this study, a normal sitting posture has an angle value between 9° and 15°, while a hunched position is characterised by an angle value ranging from 32° to 80°, according to the test table in the results and discussion. This tilt threshold is determined based on a comparison of manual data with sensor measurements to objectively distinguish between ergonomic and non-ergonomic postures.

In line with the development of Internet of Things technology, body posture and sitting duration can be tracked with high accuracy. The Internet of Things (IoT) has had a significant impact in various fields, especially in the health sector. One of the notable aspects of IoT application in the medical world is its ability to efficiently collect, process, and analyse data to support improvements in service quality and patient care [12], [13], [14], [15], [16], [17], [18]. Therefore, an IoT-based posture and sitting duration detection system has been developed to alert users if they are sitting in the wrong position or for too long.

In the previous device, only an Arduino microcontroller was used. Previously, the device only utilised Arduino without data monitoring features via an application or website, did not provide notifications via smartphone, and was not equipped with a data logger [19]. Therefore, we developed an instrument that utilises the Internet of Things (IoT) to improve the ease of use of this device.

In this study, the author used ESP32 as the main microcontroller because it has Wi-Fi connectivity so that data can be sent to Firebase for remote monitoring. Flex sensors are used to detect changes in body posture, while ultrasonic sensors are used to detect the presence of users on the chair. If the sensor detects incorrect posture or sitting duration exceeding the recommended limit, a buzzer will sound and the data will be displayed on the LCD and sent to Firebase for further analysis.

With this system, it is hoped that users will become more aware of the importance of maintaining good posture and managing sitting duration more wisely, thereby reducing the risk of health problems caused by these unhealthy habits.

## II. LITERATURE REVIEW

In previous research, the NodeMCU ESP8266 v3 Wi-Fi module is used as the main connector between sensors attached to fitness clothing and a cloud-based analysis platform. This module is responsible for sending data from two 3-axis gyroscope sensors and one EMG sensor wirelessly to platforms such as ThingSpeak. With its integrated Wi-Fi capability, NodeMCU enables real-time and efficient data transmission, supporting remote monitoring and analysis functions, as well as providing direct feedback to users via an Android application. The use of NodeMCU ensures portability and ease of integration of IoT devices in the designed smart fitness system [20].

Another study discussed about posture monitoring system developed uses four FSR pressure sensors attached to the seat cushion via a 3D-printed adapter, which is connected to an Arduino Mega microcontroller for data acquisition via a voltage divider resistor and conversion using a 10-bit ADC. The data is then processed in real time with Java-based software following the MVC architecture pattern. This system works by calibrating the sensors when first used and continuously comparing the pressure on the left and right sides of the seat to detect any asymmetrical sitting position imbalances. When detected, the software will display a visual warning and store the position shift data in a secure cloud database for further analysis. As a result, the system is able to monitor and provide automatic notifications when the sitting position is unbalanced, helping users to correct their sitting position, thereby potentially reducing the risk of musculoskeletal disorders and improving back health in the long term [21].

Another research proposed a cost-effective, privacy-preserving passive RFID-based dynamic sitting posture recognition system. The background is based on the need to monitor incorrect sitting posture, especially among adolescents, without relying on invasive technologies such as cameras or expensive sensors that have shortcomings in terms of accuracy, cost, and comfort. The system uses five passive RFID tags attached to the user's back, where phase and RSSI data from the tags are captured by a COTS (Commercial off-the-shelf) RFID reader. The obtained data is then processed through a phase unwrapping algorithm and denoising filter, then converted into Doppler shift data and RSSI differences to clarify posture changes. This entire process is supported by hardware in the form of an Impinj R420 RFID reader, directional antenna, and computer for data processing, as well as Python and PyTorch-based software for preprocessing and training the ResNet neural network model. This neural model is capable of extracting deep features from the converted data and classifying sitting postures with an accuracy rate of 99.17%, proven to be robust across various users and usage environments [22].

## III. METHOD

This research was conducted by following a systematic process, starting from a literature review to the preparation of the final report as illustrated on Figure 1. The first stage was a literature review, which involved searching for, reading, and studying journal references and books on previous research relevant to flex sensors, ultrasonic sensors, Arduino software, ESP32, and IoT control. The references collected were used as a theoretical basis and reference in designing an IoT-based system for detecting sitting time and slouching posture.

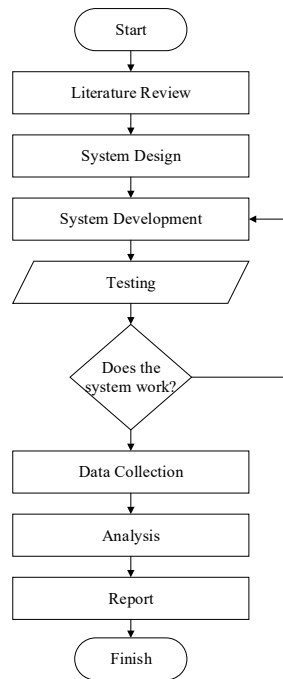


Figure 1. Workflow of Research

After the literature study was completed, it was followed by the system design stage, which included the design of the overall architecture of the device as seen on Figure 2. At this stage, a system block diagram consisting of three main parts: input, process, and output. The input part consists of a HY-SRF05 ultrasonic sensor to detect the presence of users in chairs by measuring distance, a flex sensor to detect body posture, and a DS3231 RTC module to calculate time accurately. The process section uses an ESP32 microcontroller as the system's control brain, equipped with an integrated Wi-Fi module, making it ideal for IoT applications. Meanwhile, the output section includes an I2C LCD to display local information, a buzzer as a warning alarm, and a web application for remote monitoring. In addition to the electrical system design, this stage also involved the design of the panel box construction using design software, with acrylic as the material for the electronic component housing.

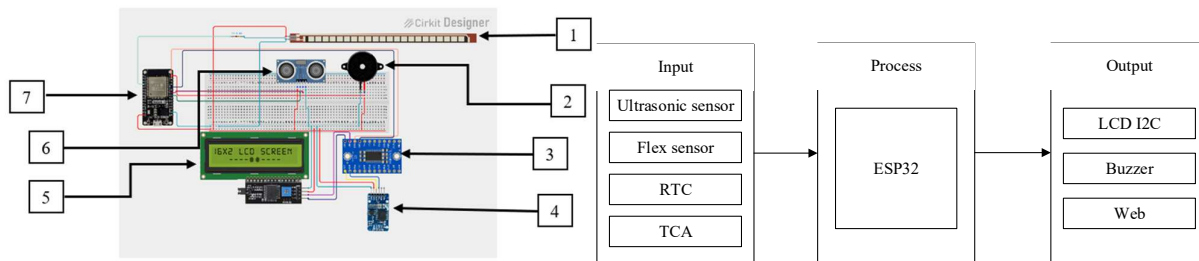


Figure 2. Hardware Schematic and Diagram Block

The next stage is system development, which includes hardware and software development. For the hardware, the components are assembled based on the previously designed electrical circuit diagram, ensuring that all connections between components such as the ESP32 (7), sensors (1: flex sensor, 3: TCA, 6: ultrasonic sensor), RTC (4), LCD (5), and buzzer (2) are installed correctly. For the software, development is carried out using Visual Studio Code with the PlatformIO extension as the development environment. The main program is written in C++ with additional libraries for sensor communication and Firebase connection. The program is designed to read sensor data in real-time, calculate sitting duration, detect posture changes based on threshold values, display data on the LCD, and send data to the Firebase Realtime Database. The web monitoring application was created using HTML and CSS to display sensor data, posture status, and buzzer controls sent from the ESP32 via Firebase. The web was designed to be responsive so that it can be accessed from various devices with a neat and easy-to-understand layout.



Figure 3. Final Product

After development was complete, a system testing phase was carried out to ensure that all components worked as designed. Testing was carried out in stages, starting from component testing to overall system testing. At this stage, verification was carried out on electrical connections, sensor reading functions, time calculation accuracy, program logic, communication with Firebase, and data display on the LCD and web. If any errors or functional inconsistencies are found, repairs and retesting are carried out until the system works properly. The system is considered successful when the sensor can accurately detect the user's presence and posture, sitting time is calculated correctly, warnings appear according to conditions, data is uploaded to Firebase in real-time, and web monitoring can display and control the system properly.

Once the system is confirmed to be working properly, the experimental data collection stage will commence. Data will be collected by conducting tests under various conditions and usage scenarios, such as variations in user distance, body posture (upright and bent over), and sitting duration. The data collected includes flex sensor readings, distances detected by ultrasonic sensors, recorded sitting times, posture detection accuracy, buzzer responses, and the stability of Firebase connections and web displays. Data collection is carried out repeatedly to obtain consistent and representative results.

The data analysis stage is carried out to evaluate system performance based on the data that has been collected. The analysis includes calculating the accuracy of the sensor in detecting presence and posture, evaluating the accuracy of the time measured by the RTC, assessing the responsiveness of the system in providing warnings, and analysing the stability of IoT communication between ESP32, Firebase, and web monitoring. The results of the analysis are used to assess whether the system has met the research objectives and to identify the strengths and limitations of the developed system.

The final stage is the preparation of a research report containing complete documentation of the entire research process, from literature study to analysis results. The report is systematically compiled to include the background of the problem, literature review, research methodology, results and discussion, as well as conclusions and suggestions. The report is supplemented with diagrams, tables, graphs, and documentation images to clarify the explanation and make it easier for readers to understand the developed system.

#### IV. RESULT AND DISCUSSION

TABLE I  
FLEX SENSOR CALIBRATION

No.	Posture	ADC Value	Manual Angle (°)	Read Angle (°)	Difference (°)
1	Normal	1472	15	14.1	0.9
2	Hunchback	1014	45	45.4	-0.4

From Table I, it can be seen that the flex sensor reads the ADC value and calculates it into degrees of bending. If the degree is  $> 32.7^\circ$ , it will display the status "bending" and the buzzer will turn ON. The LCD will display "Bending", the status will be sent to Firebase and displayed on the smartphone. Conversely, if the angle is  $\leq 32.7$ , it will display the status "Normal", the buzzer will turn OFF, the LCD will display "Normal, the status will be sent to Firebase and displayed on the smartphone.

TABLE II  
FLEX SENSOR SENSITIVITY DATA

ADC Value	Flex Angle (°)	Status
1493	12.67	NORMAL (BUZZER OFF)
1396	19.31	NORMAL (BUZZER OFF)
1367	21.3	NORMAL (BUZZER OFF)
1360	21.78	NORMAL (BUZZER OFF)
1277	27.47	NORMAL (BUZZER OFF)
1120	37.17	HUNCHBACK (BUZZER ON)
1085	39.56	HUNCHBACK (BUZZER ON)
1052	41.8	HUNCHBACK (BUZZER ON)
1023	43.79	HUNCHBACK (BUZZER ON)
980	46.68	HUNCHBACK (BUZZER ON)

Table II shows the results of testing the curvature of the flex sensor in degrees, the resulting ADC values, and the normal or bent status. The formula for calculating the resulting degrees based on the calibration used in this study is as follows.

$$\text{Flex Degree}(\text{°}) = (0.0685 \times \text{ADC}) + 114.94 \quad (1)$$

Where: ADC is the value generated from the flex sensor.

The results of flex sensor testing on this device show consistent posture detection capabilities, in line with the working principles of flex sensors that have been widely used in previous body posture detection research.

TABLE III  
COMPARISON RESULTS AND SENSITIVITY OF ULTRASONIC SENSORS

No.	Measured Distance on LCD (cm)	Measured Distance with Ruler (cm)	Timer Condition	Error Value (%)
1	9.5	9.7	Normal	2.06%
2	17.1	17.2	Normal	0.58%
3	21.3	20.9	Normal	1.91%
4	25.1	24.9	Normal	0.80%
5	27.4	27.5	Normal	0.36%
6	29.4	29.6	Normal	0.68%
7	33.5	34	Stop	1.47%
8	40.4	41.7	Stop	3.12%
9	52.5	53.6	Stop	2.05%
10	57.2	57.6	Stop	0.69%
Average Error Value				1.37%

Table III above shows the data we obtained from measuring the distance of the ultrasonic sensor from the LCD display and direct measurements using a ruler, as well as the sensitivity of the sensor. The sensitivity of the ultrasonic sensor appears normal from data 1 to 6, but from data 7 to 10, the ultrasonic sensor does not detect or count the timer anymore. The comparison was then used to calculate the percentage error and its average. The smallest percentage error was in data point 5, and the largest was in data point 8. The average percentage error was 1.37%. The following is the formula for calculating the percentage error and its average.

$$\text{Error} (\%) = \left| \frac{\text{LCD value} - \text{Value from ruler}}{\text{Value from ruler}} \right| \times 100\% \quad (2)$$

Data points 1 and 3 in Table III may have been measured inaccurately, resulting in a high error percentage. Data points 8 and 9 show a high error percentage because the measurement process used a ruler that was only 30 cm long, so for distances greater than 30 cm, two measurements were taken. There may have been excess or deficiency in these measurements, resulting in a fairly large error value. The accuracy of the ultrasonic sensor's distance detection is 1.37% (Table III), indicating that this sensor is reliable enough to detect the presence of users, which is an improvement over the previous system that may not have had a specific user presence detection feature.

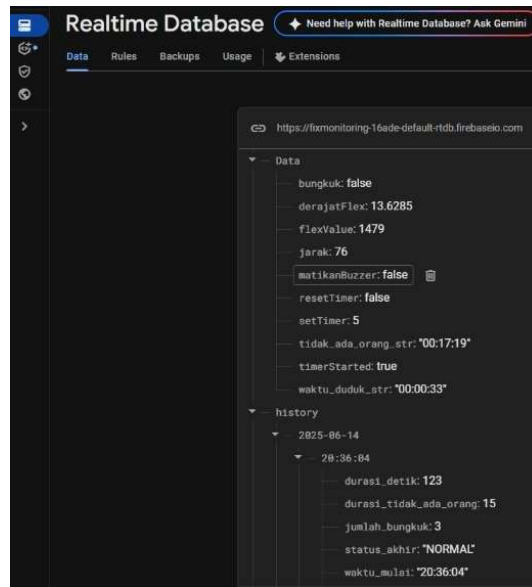


Figure 4. Firebase Results

The analysis of the Real-time Database in the Monitoring Application is shown in Figure 4. Figure 4 shows the results from Firebase. Realtime Database is one of Firebase's services that functions to store and synchronise data directly (in real time), allowing users to interact with constantly updated data without needing to refresh the page. The image above shows the data structure stored in Realtime Database. The following are some important elements listed in the data, including:

- bent: (boolean) Status of whether bent or not (false).
- degreeFlex: (float) Flexibility degree value (14.108).
- flexValue: (integer) Flexibility value amount (1472).
- distance: (integer) Specific distance in the application (2).
- no\_one\_detected\_str: (string) Time when no one was detected (“00:00:16”).
- sitting\_time\_str: (string) Total time spent sitting (“00:03:39”).

### Monitoring Duduk & Postur

Status Postur: **NORMAL**

Derajat Tekukan: **2.0°**

Jarak Terbaca: **0 cm**

**Matikan Buzzer**

**Atur Waktu Timer**

0 : 1 : 0











**Kirim Timer**

Tanggal	Jam	Lama Waktu Duduk (detik)	Bungkuk	Tidak Ada Orang	Status
2025-06-24	03:26:49	60	3	5	NORMAL
2025-06-24	02:01:11	180	0	28	NORMAL
2025-06-23	23:09:07	180	0	0	NORMAL
2025-06-20	21:35:10	120	5	2	NORMAL
2025-06-17	00:43:18	60	0	95	NORMAL
2025-06-17	00:10:04	60	0	6	NORMAL
2025-06-16	23:59:40	60	2	0	NORMAL
2025-06-16	23:13:56	300	2	12	NORMAL

Figure 5. User Interface of the Website

Figure 5 shows the design code from Visual Studio Code software. The data displayed includes posture status (normal/hunched), the degree of flex sensor bending, and the reading distance from the ultrasonic sensor. The “Turn off Buzzer” button resets the buzzer or turns it off. We can also set the timer to the desired hours, minutes, and seconds. Below that, there is also a date history feature. We can select the date for which we want to view the monitoring data and can also download the history as a “json” file. Finally, there is a history of the last sitting monitoring per date. So, we can see the details of when we started using the tool.

TABLE IV  
 PERFORMANCE RESULTS

No.	Subject	Status		Degree	
		Normal	Hunchback	Normal	Hunchback
1.	First subject			14	45
2.	Second subject			13	40
3.	Third subject			9	32
4.	Fourth subject			15	37
5.	Fifth subject			13	80

Next is the Degree Test Using Subjects. This section contains a table/data on individual data collection, including the start time, as shown in Table IV.

Based on the test results in Table 4 above for five users, comparative data was obtained on the angle of body curvature when sitting in a normal position and in a hunched position. In the normal position, the degree of curvature ranged from 9° to 15°, indicating a relatively upright and ergonomic posture. Meanwhile, in a hunched position, there was a significant increase in the angle, with values ranging from 32° to 80°, indicating a less-than-ideal sitting posture and the potential for spinal problems if maintained for long periods of time. The difference in degree values shows that the system is able to detect changes in body posture quite clearly, making it valid as a basis for monitoring body posture in research.

The device's ability to detect a hunched posture and provide warnings, as well as record sitting duration and the number of times the user is hunched over, is a significant improvement over previous devices that only focused on posture detection without historical data monitoring and real-time notification features.

In the Timer Testing Using Subjects, there is a table containing the start time, end time, timer setting (seconds), accurate difference (seconds), and accurate error (seconds). The results are shown in Table V below.

TABLE IV  
 PERFORMANCE RESULTS

No.	Start Time	End Time	Timer Setting (seconds)	Actual Difference (seconds)	Actual Error (seconds)
1	23:57:58	00:26:46	600	1728	1128
2	00:29:18	00:44:38	300	920	620
3	00:47:38	00:56:49	120	551	431
4	00:57:39	01:04:07	120	388	268
5	01:06:50	01:49:25	900	2555	1655

Based on Table V, the test results show “Accurate Error (seconds)”. The “Accurate Error (seconds)” column represents the difference between “Accurate Difference (seconds)” and “Set Timer (seconds)”. In other words, the value in the “Accurate Error (seconds)” column indicates the magnitude of the error between the actual measured time duration (“Accurate Difference”) and the time duration that has been determined or set on the timer (“Set Timer”). The larger the error value, the greater the discrepancy between the expected time and the actual time recorded by the testing system.

A comparison between the actual sitting time and the set timer time shows that all data has a significant positive time difference, with an average error of around 820 seconds (±13 minutes). This is likely due to delays in reading the ultrasonic sensor due to the trigger-echo process, which is not always real-time, as well as delays in sending data to Firebase, which hinders the main loop of the ESP32. Ultrasonic sensors such as HY-SRF05 require a pause between readings, and if not controlled in a non-blocking manner, readings can be delayed or fail, causing the system to still consider the user to be seated even though they are no longer there. This condition indicates that the monitoring system still needs to be optimised, both in terms of sensor reading logic and data transmission management, in order to calculate sitting time accurately and responsively.

## V. CONCLUSION

Based on the results of testing and discussion, it can be concluded that the IoT-based device for detecting sitting time and body posture that has been designed can function properly in accordance with the research objectives. Testing of the flex sensor showed consistent posture detection capabilities with a threshold of  $32.7^\circ$ , where normal posture produced values between  $9^\circ$  and  $15^\circ$  and slouching posture between  $32^\circ$  and  $80^\circ$ . The HY-SRF05 ultrasonic sensor showed a good level of accuracy with an average error percentage of 1.37% in detecting the presence of users. The integration of the system with the Firebase Realtime Database and web-based monitoring application was successfully implemented, allowing users to monitor posture status, flexibility degree values, detected distance, sitting time, and usage history in real-time remotely, as well as control the buzzer and set the timer through a responsive web interface. However, testing the timer using subjects revealed limitations in the system's accuracy in calculating sitting time, with an average error of approximately 820 seconds or 13 minutes, likely caused by delays in reading the ultrasonic sensor and sending data to Firebase, which hindered the main loop of the ESP32. Although optimisation of the sensor reading logic and data transmission management is still required to improve the accuracy of time calculations, this system has proven its potential as a practical solution to help users monitor their sitting habits and maintain an ergonomic posture to prevent spinal health problems.

## VI. CONFLICT OF INTEREST

The authors declare no conflict of interest.

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