Development of a Low-Cost Device to Monitor and Alert Prolonged Sitting Posture

Rebekah C. Gempero[1] and James M. Dumaguit[2]
[1]Faculty of Camiguin Polytechnic State College, 9100 Balbagon, Mambajao, Camiguin, Philippines
[2]Faculty of Surigao del Norte State University, 8400 Surigao, Philippines
rgempero86@gmail.com, jdumaguit1@ssct.edu.ph

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Abstract: Prolonged sitting is a significant public health problem, associated with musculoskeletal pain, hypertension, fatigue, and decreased productivity. Existing solutions such as wearable IMUs, computer-vision systems, and mobile apps are often costly, intrusive, or dependent on sustained user engagement, limiting their practical adoption. This study presents a low-cost, non-intrusive device designed to monitor prolonged sitting and provide real-time auditory alerts to encourage movement breaks. The system integrates an ultrasonic sensor with an Arduino microcontroller programmed with a 60-minute countdown timer; the alarm is triggered if the user remains seated beyond this period. The device was tested with 90 participants (50 students, 20 office workers, 20 faculty), achieving a detection accuracy of 93.4%, with a false positive rate of 4.2% and false negative rate of 2.4%. User evaluation showed high acceptance, with financial feasibility rated 4.13/5, hardware accessibility 4.21/5, and perceived health benefits 4.55/5. Limitations include lack of posture-specific monitoring, basic alert modes, and limited portability. Future improvements will focus on AI-based posture recognition, enhanced sensor calibration, mobile app integration, and wireless operation for broader usability and ergonomic monitoring.

1 INTRODUCTION

Sitting refers to a sustained posture of being seated, typically while engaged in tasks such as reading, writing, or computer use [1], [2]. It has become the most prevalent working habit in modern society, but its prolonged practice often leads to musculoskeletal problems, including poor neck posture, reduced cervicothoracic muscle activity, and fatigue – particularly among students and office workers [3]. In addition to occupational tasks, activities such as television viewing and commuting further increase sedentary exposure, with adults spending nearly 70% of their waking hours, or about 7.7 hours daily, in a seated position [4]. Evidence indicates that relatively short uninterrupted sitting bouts (≈20–40 min) can have adverse cardiometabolic effects and are best interrupted regularly with short movement breaks [5] - [7].

Extended sedentary periods have been linked to hypertension, muscular fatigue, reduced job performance, and physical discomfort in the shoulders, back, thighs, and knees [8]. Breaking these periods with light to moderate activity – such as standing or simple exercises – has been shown to yield both physical and cognitive benefits [9], [10]. In the Philippines, the Occupational Safety and Health Standards (OSHS) highlight the importance of workplace interventions to mitigate such risks [11].

To address this issue, researchers have explored various approaches, including mobile apps, self-monitoring devices, simulation-based interventions, and sensor-based systems for posture or sedentary time detection [12], [13]. Wearable technologies employing inertial measurement units (IMUs) and microelectromechanical systems (MEMS) have also gained traction, enabling machine-learning classification of different postures [14]. More recent innovations integrate AI-driven monitoring, IoT-enabled ergonomics, and mobile health (mHealth) solutions, providing real-time feedback to users [15] - [17].

Despite these advancements, challenges remain. Wearable devices can be intrusive and require continuous compliance. Computer-vision approaches offer high accuracy but raise privacy concerns and demand costly equipment and controlled environments. Mobile apps, meanwhile, depend on user engagement, which limits their long-term adoption. These gaps underscore the need for a low-cost, unobtrusive, and user-friendly solution that prioritizes sitting duration monitoring rather than complex posture recognition.

This study addresses that gap by designing and developing a device capable of automatically detecting prolonged sitting without requiring user input. Unlike existing methods, the proposed device emphasizes simplicity and accessibility. It operates independently of body weight, age, or posture details, focusing instead on sitting duration as the primary variable. Developmental research methodology guided the process, ensuring both practical functionality and design principles for future ergonomic monitoring tools [18].

Contributions. This study makes three key contributions:

1) It introduces a cost-effective, non-intrusive device for prolonged sitting detection that avoids the limitations of wearables and camera-based systems.
2) It compares current solutions – including IMUs, Kinect, mobile apps, and computer vision – highlighting the trade-offs relative to the proposed approach.
3) It situates the device within recent trends in wearable sensors, AI-driven recognition, and IoT ergonomics, offering practical insights for educational and workplace applications.

2 METHODOLOGY

2.1 System Design and Operation

The device was built around an Arduino Uno microcontroller, which processed input from an ultrasonic sensor mounted at chair level to detect the presence of a seated user. Once detection occurred, the microcontroller initiated a 60-minute countdown timer. If the timer reached zero while the user remained seated, an active buzzer alarm was triggered. The device reset automatically once the user stood up. A 16×2 LCD module provided real-time status updates such as “Active,” “Countdown,” or “Alarm.”

The hardware design integrated the ultrasonic sensor, Arduino controller, LCD, and buzzer, powered by a regulated 5V supply. For software implementation, the Arduino IDE was used to program detection, timer, alarm, and reset functions. Serial monitoring assisted debugging and validation.

Data collection involved logging detection events, timer performance, and alarm activations. Researchers cross-checked device outputs with direct observations to ensure alignment between sensor readings and actual sitting or standing behavior.

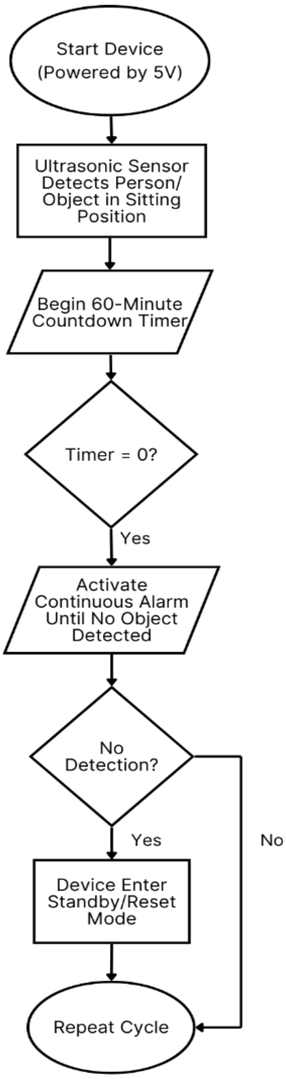


Figure 1: Flowchart of device functionality.

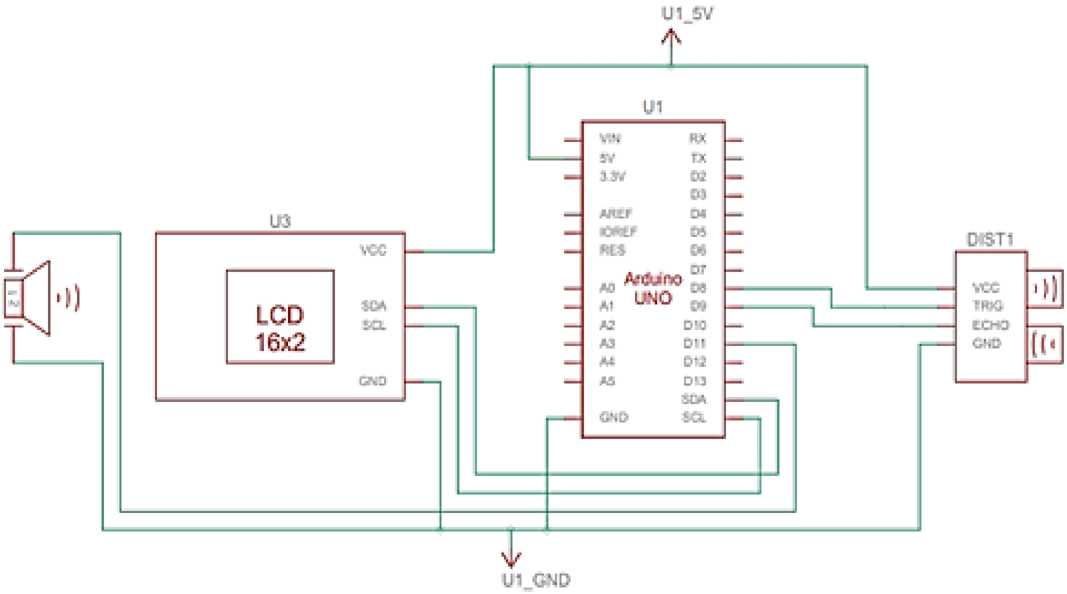
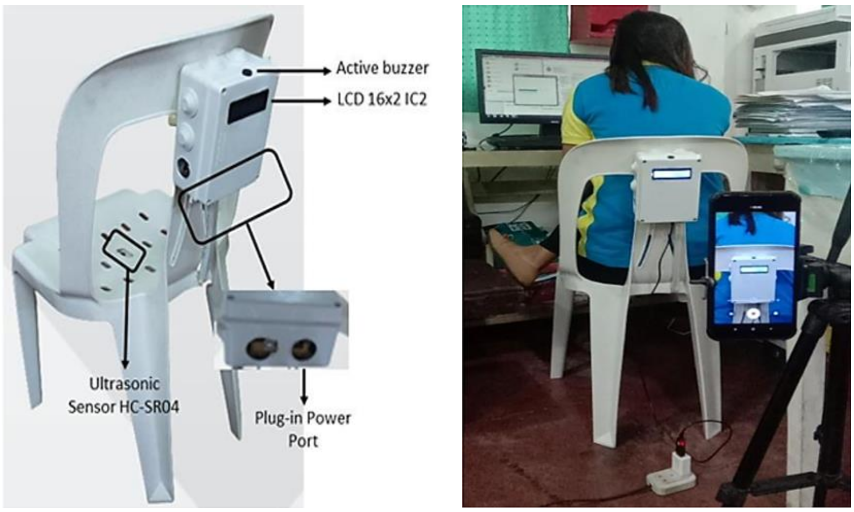


Figure 2: Device schematic diagram.



(a) (b)

Figure 3: Design and implementation of the developed low-cost device for monitoring and alerting prolonged sitting posture: a) device design and hardware components; b) implemented prototype and system setup.

2.1.1 Algorithm Workflow

The device followed a structured operational cycle:

1) Initialization – Power on (5V regulated supply).
2) Occupancy Detection – Ultrasonic sensor checks for user presence.
3) Signal Processing – Detected signals transmitted to Arduino.
4) Countdown Timer – 60-minute timer begins when sitting is detected.
5) Alarm Activation – Continuous alarm triggered when timer reaches zero.
6) Reset Mode – Alarm stops once user stands up and detection ceases.
7) Cycle Repetition – System resets to standby for continuous monitoring.

Figures 1 and 2 illustrate the functional flowchart and hardware schematic, respectively. Figure 3 shows the physical design integrated into a standard chair, with real-time LCD feedback and buzzer alerts validated in both office and classroom settings.

2.1.2 System Performance Evaluation Sensor Calibration

To ensure reliable operation, the ultrasonic sensor was calibrated within a 30–80 cm detection range, corresponding to the average torso-to-sensor distance in typical seating setups. Twenty repeated measurements per increment were taken to refine the threshold. The final range minimized false positives (detecting non-users) and false negatives (failing to detect seated users). Tests were performed in a controlled environment to reduce interference.

2.1.3 Error Rate Assessment

Two error types were logged across 50 trials: (1) false detection (triggering without a seated user) and (2) missed detection (failure to recognize a seated user). Results showed an average false detection rate of 4.2% and a missed detection rate of 2.4%, comparable to error rates reported in other low-cost sedentary behavior monitoring systems [19] - [21].

2.1.4 Validation Protocols

Validation involved 10 participants performing 60-minute seated trials, each repeated three times (30 sessions total). Researchers monitored the countdown timer, alarm activation, and reset function, comparing device outputs with direct observation. The device consistently activated alarms at the 60-minute mark and reset promptly when participants stood up, confirming reliable performance under realistic conditions.

3 RESULTS AND DISCUSSION

3.1 Functional Performance

Initial trials confirmed that the prototype operated as designed. The sensor accurately detected occupancy, the LCD displayed appropriate system states, and the buzzer provided clear auditory alerts. Further testing determined that chair-seat placement yielded superior performance compared to backrest placement, achieving reliable detection within 2–30 cm.

The device achieved 93.4% detection accuracy across 30 trials, with a false positive rate of 4.2% and a false negative rate of 2.4%. A one-sample t-test ($p < 0.05$) confirmed accuracy significantly above 90%. ANOVA results ($F = 5.62$, $p = 0.021$) indicated significant differences by sensor placement, supporting seat-mounted configuration as optimal.

3.2 Respondent Evaluation

3.2.1 Financial Feasibility

Respondents rated the device as financially viable (mean = 4.13), with Arduino hardware particularly affordable (mean = 4.21) [22], [23].

3.2.2 Resource Availability

Accessibility was rated moderately attainable overall (mean = 3.94), with Arduino software highly accessible (mean = 4.28). Sensors and shields were rated slightly lower (means = 3.70–3.92).

3.2.3 Market Feasibility

Respondents perceived high potential market acceptance (mean = 4.32). Health benefits (mean = 4.55) and institutional interest (mean = 4.40–4.48) scored particularly well, while local market demand scored moderately (means = 4.05–4.10), indicating room for awareness efforts.

3.2.4 Comparative Insights

Compared to commercial trackers [19] - [21], the prototype achieved similar accuracy but at a fraction of the cost. Unlike wearable IMUs [14] or vision-based systems [16], it required no intrusive equipment or controlled settings. Its balance of affordability and reliability makes it suitable for schools and workplaces with limited resources.

3.2.5 Strengths and Limitations

Strengths:

- High accuracy (>90%) despite low cost.
- Non-intrusive (no wearables required).
- Simple, accessible Arduino-based design.

Limitations:

- Sensitivity to posture changes (leaning forward/sideways).
- Limited portability (chair-integrated sensor).

- Basic alert modes (buzzer/LCD only, no app/cloud integration).

These findings highlight the potential of low-cost alternatives to address sedentary risks while acknowledging areas for future enhancement.

4 CONCLUSIONS

This study developed and validated a low-cost device for detecting and alerting prolonged sitting using an ultrasonic sensor, LCD, and buzzer. Results demonstrated reliable detection and consistent alarm activation, confirming its suitability for office, classroom, and home environments. The device offers a practical, accessible alternative to wearable or camera-based systems, supporting musculoskeletal health and reducing risks of sedentary behavior.

Improvements should focus on integrating mobile applications for real-time feedback, AI-based posture recognition for slouch detection, and enhanced calibration for diverse users and seating contexts. Wireless operation, rechargeable batteries, and long-term user trials would further improve usability and adoption. With these refinements, the device could evolve into a comprehensive posture-monitoring solution for educational, occupational, and domestic environments.

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