

Research Article



HerEase: Smart Period Pain Relief and Hygiene Belt

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Abstract

Menstrual pain and hygiene management remain significant concerns for many women, while existing solutions such as pain medication and heating pads often provide only temporary relief without personalized monitoring. To address this gap, this paper presents HerEase, an IoT-enabled smart wearable belt that combines controlled heat therapy, vibration-based pain relief, and real-time moisture monitoring using a capacitive moisture sensor. The system is powered by an ESP32 microcontroller, which regulates temperature through the Steinhart-Hart algorithm and provides wireless access to a browser-based dashboard without requiring a dedicated mobile application. Experimental evaluation demonstrated reliable performance, achieving $\pm 0.72^{\circ}\text{C}$ temperature accuracy, 96.7% moisture detection reliability, and stable operation through a soft-start mechanism that eliminated ESP32 reset issues. User testing with 20 participants resulted in an average satisfaction rating of 4.6/5.0. By integrating heat therapy, vibration therapy, moisture sensing, pad replacement reminders, menstrual cycle tracking, and a web-accessible interface into a single affordable wearable device, HerEase offers a practical solution for improving menstrual comfort and hygiene management.

Keywords: IoT; Menstrual health; Dysmenorrhea; Hygiene monitoring; Vibration therapy; Thermal feedback; ESP32; Heating therapy; Pain relief; PWM control.

1. Introduction

Menstrual pain and hygiene management remain important concerns for many women. During menstruation, discomfort and abdominal cramps can affect daily activities such as studying, working, travelling, and resting. Dysmenorrhea is one of the most common menstrual health problems and often causes pain, fatigue, and reduced productivity.^[1,2] Although a variety of menstrual products are available today, most of them are mainly designed to provide hygiene support and do not actively help in monitoring health conditions or managing pain.^[3] In recent years, there has been growing interest in the use of wearable devices for healthcare applications. These devices offer a convenient way to provide support, monitor health parameters, and improve user comfort during daily activities. As technology becomes more accessible, researchers are exploring methods to combine therapeutic functions with monitoring capabilities in order to develop practical and user-friendly healthcare solutions.^[4] Many women use pain-relief medicines, hot water bags, or heating pads to reduce menstrual discomfort. While these methods can provide temporary relief, they often lack proper control, monitoring, and personalization. Continuous use of medication may not always be preferred, and traditional heating methods generally do not provide feedback regarding temperature or safety conditions.^[5,6] In addition, most existing products focus on a single function and do not address both pain management and hygiene awareness together.

Recent developments in IoT and embedded systems have made it possible to design compact healthcare devices with sensing, control, and wireless communication capabilities. Microcontrollers such as the ESP32 can collect sensor data, control therapy modules, and provide real-time monitoring through web-based interfaces.^[7,8] These technologies create opportunities for developing smarter wearable systems that are simple, portable, and easy to use. To address these challenges, this paper presents HerEase, a smart wearable therapy belt designed to support menstrual pain relief and hygiene monitoring. The proposed system combines heat therapy, vibration therapy, moisture detection, and wireless monitoring in a single wearable device. Using an ESP32 controller and sensor-based feedback, the system provides safe operation, real-time monitoring, and improved user convenience. The aim of HerEase is to offer an affordable and practical solution that enhances comfort, hygiene awareness, and overall menstrual care experience.^[9,10]

2. Literature review

Over the past decade, significant efforts have been made to develop non-pharmacological solutions for managing menstrual discomfort. Heat therapy has remained one of

the most commonly recommended approaches because controlled warmth can help relax abdominal muscles and reduce cramp intensity. Several studies have reported that maintaining moderate therapeutic temperatures can provide effective pain relief without the side effects associated with frequent medication use.^[11,12] However, many commercially available heating products offer only basic functionality and provide limited control over temperature regulation. Researchers have also explored alternative therapeutic techniques to improve menstrual pain management. Among these, nerve stimulation and vibration-based approaches have shown promising results in reducing discomfort and improving user comfort.^[13-15] These methods are generally non-invasive and can be integrated into portable devices. While positive outcomes have been reported, most existing solutions are designed to perform a single therapeutic function and do not include additional features related to menstrual health monitoring. The emergence of IoT-enabled healthcare devices has expanded the possibilities for wearable menstrual care systems. Recent studies have demonstrated that wireless communication and embedded sensing technologies can be used to monitor health-related parameters and provide remote access to device information.^[16,17] These developments have improved user convenience and enabled real-time interaction with wearable devices. Nevertheless, many of the reported systems focus on either therapy or monitoring, rather than addressing both requirements within a unified platform. Advances in wearable electronics have further improved the practicality of healthcare devices. Lightweight sensors, compact embedded systems, and low-power communication technologies have made it possible to design wearable products that can be used comfortably for extended periods. Platforms such as the ESP32 are widely adopted because they support sensor integration, wireless connectivity, and real-time processing within a compact architecture.^[16] These capabilities make them suitable for developing portable healthcare solutions that require continuous monitoring and control.

Safety remains a critical consideration in wearable therapeutic devices. Accurate temperature measurement and controlled heating mechanisms are essential to prevent discomfort or skin damage during prolonged use. Researchers have proposed various calibration and control methods to improve temperature accuracy and maintain safe operating conditions.^[18,19] Similar control techniques have also been applied to vibration systems to ensure stable operation and a consistent user experience.^[20] Such safety-oriented approaches are particularly important in wearable products that maintain direct contact with the body. Another area of growing interest is menstrual hygiene monitoring. Sensor-based systems have been developed to detect

moisture levels and provide timely alerts when replacement of hygiene products may be required.^[21] These solutions help improve user awareness and support better hygiene practices. However, most available systems are designed to perform only monitoring functions and do not provide therapeutic assistance. In addition to wearable devices, mobile health applications have become popular tools for menstrual cycle tracking and symptom recording. These applications help users monitor cycle patterns and improve awareness of reproductive health.^[22,23] Although they provide useful information and prediction capabilities, they typically rely on manual data entry and do not offer direct pain-relief features.

From the reviewed studies, it can be observed that

heat therapy, vibration-assisted treatment, hygiene monitoring, and cycle tracking have largely been developed as separate solutions. Limited research has focused on integrating these functions into a single wearable platform. This gap highlights the need for a comprehensive system that can provide both therapeutic support and menstrual health monitoring. The proposed HerEase system addresses this requirement by combining controlled heat therapy, vibration assistance, moisture-based hygiene detection, menstrual cycle tracking, and IoT connectivity within a single wearable device. The integration of these features aims to improve convenience, safety, and overall user experience during menstrual care. Comparative Literature Review

Summary is shown in [Table 1](#).

Table 1: Comparative literature review summary.

Paper [Ref]	Authors	Issue addressed	Methodology	Technology used	Key outcomes	Results	Limitations	Future scope
Heat Patch ^[24,25]	Sitthisaknawakul W., Chantanavilai S.	Dependency on medication for menstrual pain relief	Randomized controlled trial	Heat patch therapy	Pain relief comparable to ibuprofen	Significant reduction in pain	No smart monitoring system	Adaptive portable heat therapy
TENS Cochrane ^[26]	Gibson W., Wand B. M.	Side effects of pain medications	Systematic review	TENS device	Pain reduction through nerve stimulation	Effective pain management observed	Fixed stimulation settings	Closed-loop smart TENS systems
Vibration + Heat ^[27]	J. Yoo <i>et al.</i>	Limitations of traditional therapy methods	Clinical trial	Heat and vibration therapy	Improved comfort and pain reduction	Positive clinical outcomes	No personalized control	Smart wearable therapy belt
MIMA 2.0 ^[28]	Jyothish Kumar <i>et al.</i>	Multiple menstrual healthcare challenges	Survey and prototype development	IoT with heating module	Multi-functional wearable support	Positive user feedback	Limited validation testing	Integrated health monitoring
IoT Cup ^[29]	Selva Perumal, V.R. Vadivel	Lack of menstrual flow monitoring	Prototype testing	Capacitive sensing with IoT	Real-time flow monitoring	Accurate flow detection	No therapy integration	Combined monitoring and therapy
MenstruLoss ^[30]	Mukherjee M., Naqvi S.	Menstrual pad hygiene monitoring gap	Sensor calibration testing	Capacitive ADC sensing	Saturation alert system	High detection accuracy	Tested on limited pad types	Multi-brand automatic calibration
Wearable Track ^[31]	Chang J., L. Nguy	Lack of integrated cycle tracking	Literature review	Mobile health application	Identified wearable feature gaps	Highlighted need for integration	No therapy support	Unified menstrual healthcare platform
FIR Belt ^[32]	Ke Y., M. Ou M. C.	Heat therapy efficiency improvement	Double-blind randomized trial	Far-infrared wearable belt	Improved blood circulation and pain relief	Reduced menstrual discomfort duration	Risk of overheating	Adaptive smart thermal materials

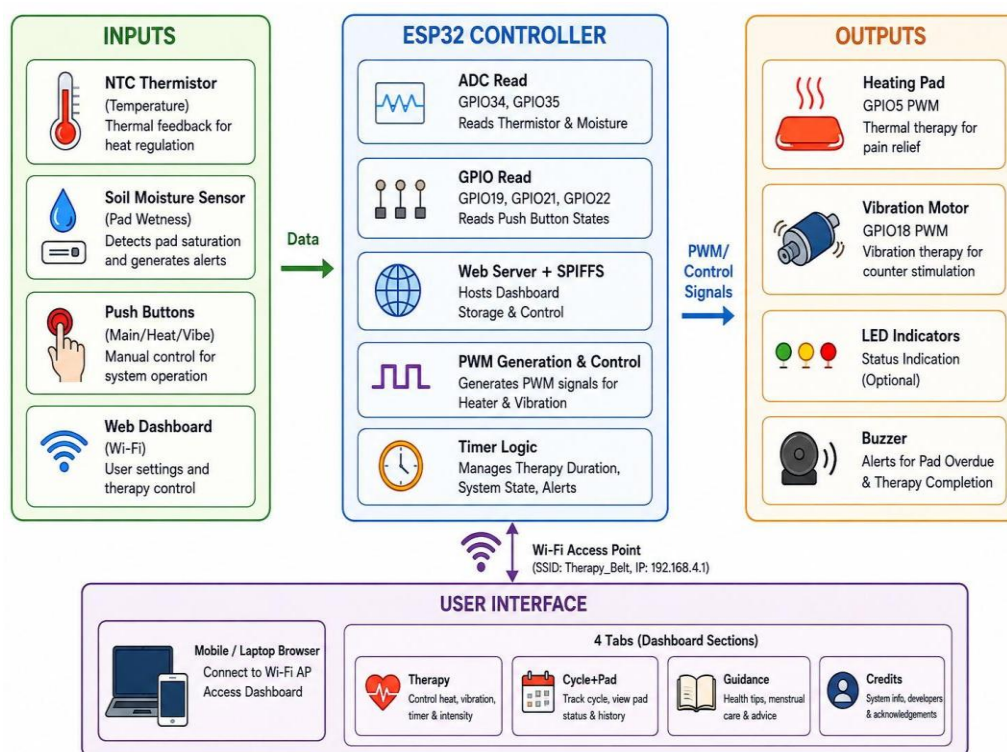


Fig. 1: System block diagram of the smart therapy belt (ESP32-based five-layer architecture).

3. Methodology

HerEase is an ESP32-based wearable device developed to provide menstrual pain relief, hygiene monitoring, and smart therapy control within a single platform. The device combines sensing, therapy management, wireless communication, and user interaction modules to support safe and convenient menstrual care. The overall operation and architecture of the proposed device are illustrated in Fig. 1. The overall operation of the device is represented through the system block diagram, circuit design, and firmware workflow.

The hardware architecture is divided into four functional sections: sensing unit, control unit, therapy unit, and user interface. The sensing unit consists of an NTC thermistor and a capacitive moisture sensor. The thermistor continuously monitors the temperature of the heating pad to ensure that the therapeutic temperature remains within a safe operating range.^[33] The moisture sensor measures pad saturation levels and generates a hygiene notification whenever the measured value crosses the predefined threshold.^[34] Manual control buttons are also provided for power control and therapy selection.

The ESP32 functions as the central controller of the device. It receives data from the sensing unit, processes user inputs, and executes the required control actions. Based on real-time temperature feedback, PWM signals are generated to regulate the heating pad and maintain comfortable therapy conditions. The controller also manages vibration intensity, therapy timing, menstrual

cycle tracking, and notification functions. User preferences and cycle-related information are stored locally using SPIFFS memory to ensure data retention during device restart or power interruption.^[35] The therapy section includes a flexible heating pad and a vibration motor. The heating pad delivers controlled thermal therapy to help reduce menstrual cramps, while the vibration motor provides additional comfort through gentle stimulation.^[36] A soft-start control mechanism is implemented to prevent sudden current surges during motor activation and improve operational stability. Status indicators are used to display active modes, alerts, and connectivity information.

Wireless monitoring and control are provided through an ESP32-hosted web dashboard. By connecting to the device over Wi-Fi, users can monitor temperature readings, therapy status, moisture levels, and cycle information in real time. The dashboard also allows adjustment of heating intensity, vibration settings, therapy duration, and notification preferences. To improve safety, the firmware incorporates temperature limit protection, automatic shutdown under abnormal conditions, and timer-based therapy control. Through the integration of heat therapy, vibration support, hygiene awareness, cycle tracking, and wireless monitoring, HerEase offers a practical and user-friendly solution for menstrual health management.

HerEase provides a browser-based interface that allows users to interact with the wearable device without installing a dedicated mobile application. The ESP32

operates in Wi-Fi Access Point mode, enabling direct connection through a smartphone, tablet, or laptop. Once connected, users can access the dashboard to monitor therapy status, view menstrual cycle information, track hygiene conditions, and modify device settings. The interface is designed to provide quick access to essential functions while maintaining a simple and user-friendly experience. The overall firmware operation and decision-making process of the proposed system are illustrated in Fig. 2. When the device is powered on, the ESP32 loads previously saved preferences, initializes the sensing and therapy modules, and activates the wireless dashboard service.^[37] User-selected settings such as therapy duration, language preferences, and notification options are retrieved from internal memory to maintain a personalized experience. PWM channels used for heat and vibration control are also configured during this stage to ensure stable operation.^[38]

During normal operation, temperature and moisture data are collected at regular intervals. The temperature monitoring routine helps maintain safe heating conditions by continuously adjusting the heating output according to sensor feedback.^[39] Simultaneously, the moisture sensing module evaluates pad wetness levels and generates a hygiene reminder whenever the measured value exceeds the predefined threshold.^[40] These functions allow users to receive real-time information regarding both therapy and hygiene conditions. The firmware also manages manual control inputs and therapy scheduling. Physical buttons enable quick control of heating and vibration modes, while software-based debounce logic ensures reliable input detection. A built-in timer tracks the selected therapy duration and automatically stops the active session when the configured time limit is reached. This feature improves safety, reduces unnecessary power consumption, and prevents prolonged exposure to heat therapy.^[41]

While a therapy session is active, the controller regulates both the heating pad and vibration motor according to user-selected settings. Gradual activation and controlled intensity adjustment are implemented to improve comfort and maintain stable performance. Through the combined operation of sensing, therapy control, hygiene monitoring, cycle tracking, and wireless communication, HerEase delivers a responsive and convenient menstrual healthcare experience. The hardware architecture of HerEase is centered on the ESP32 DevKit, which serves as the main control unit for sensing, therapy management, and wireless communication, as shown in Fig. 3. The system is powered through a 5 V USB supply and integrates a moisture sensor, temperature sensor, heating pad, vibration motor, buzzer, push buttons, and an I2C LCD display. The moisture sensor is connected to an analog

input of the ESP32 for pad wetness monitoring, while the temperature sensor positioned near the heating pad provides feedback for temperature regulation. Two push buttons are provided for manual activation of heat and vibration therapy modes. A 16×2 I2C LCD displays important system information such as temperature readings, therapy status, and alerts.

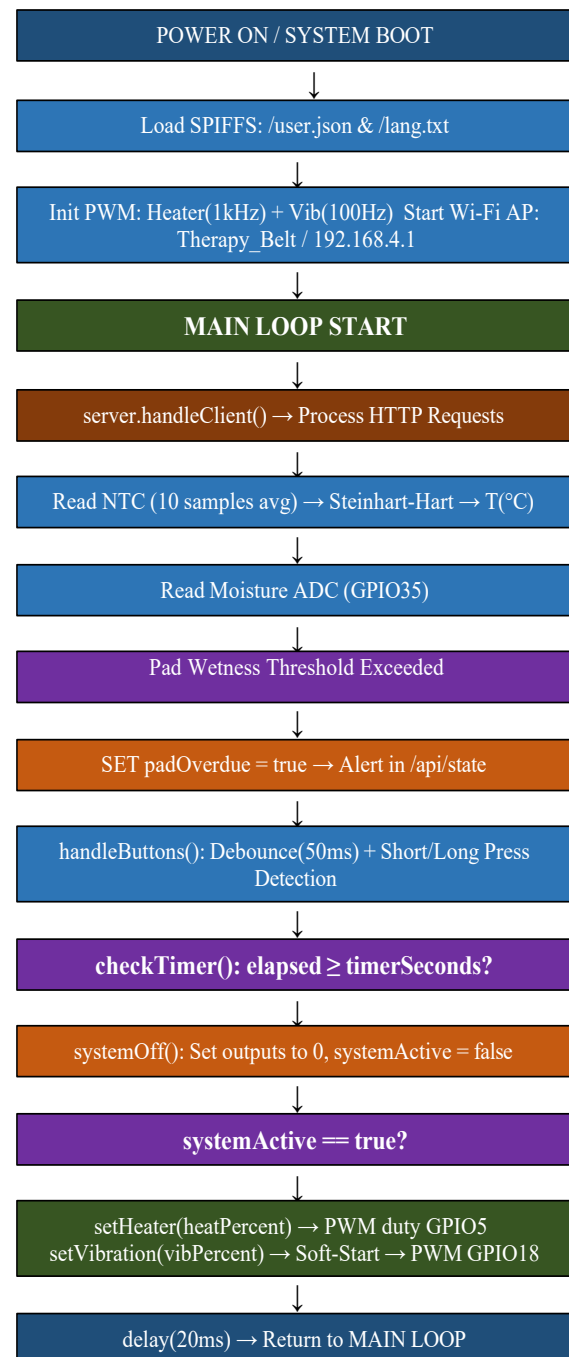


Fig. 2: Firmware functional flowchart of the smart therapy belt (ESP32).

The heating pad and vibration motor are driven through MOSFET-based switching circuits controlled by PWM signals generated by the ESP32. This arrangement allows adjustable therapy intensity and efficient power

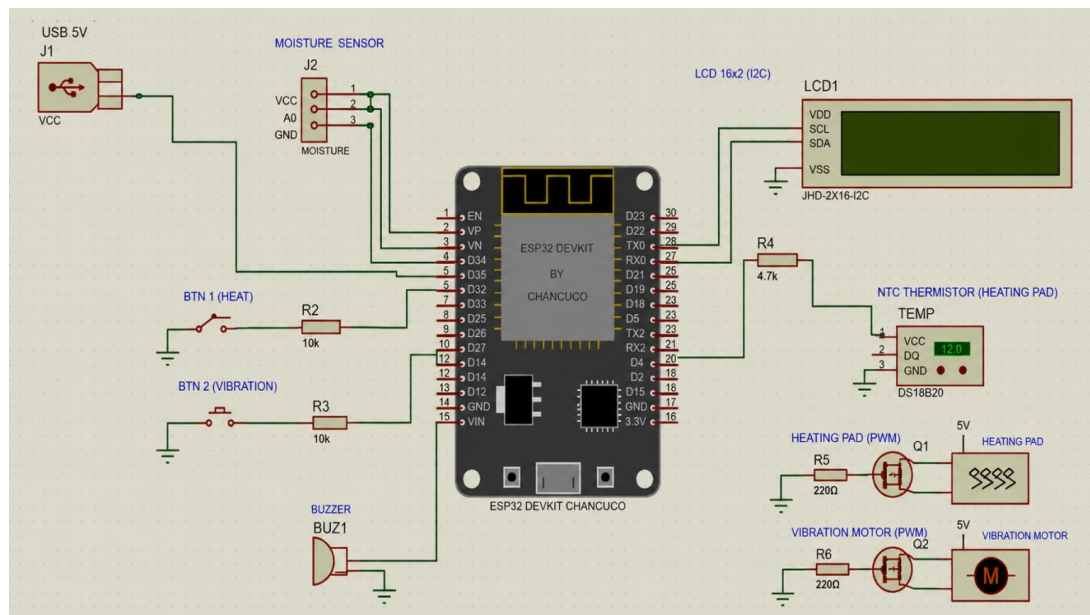


Fig. 3: Hardware circuit diagram (ESP32 DevKit with NTC Thermistor; Moisture Sensor; MOSFET, LCD, Buzzer).

control. A buzzer is included to provide audible notifications for hygiene reminders and system alerts. The integration of sensing, therapy, display, and notification modules within a single ESP32-based platform enables compact, reliable, and user-friendly operation for menstrual health management.^[42–45]

4. Results

The performance evaluation of HerEase confirmed reliable operation across sensing, therapy, monitoring, and communication modules. The temperature sensing unit achieved an accuracy of approximately $\pm 0.72^{\circ}\text{C}$, providing dependable feedback for PWM-based heat regulation. During testing, the heating pad-maintained temperatures between 38°C and 45°C , which are suitable for menstrual pain relief while remaining within safe operating limits.^[46] The moisture monitoring module successfully detected pad saturation conditions and generated hygiene notifications whenever sensor readings crossed the predefined threshold. No false alerts were observed during the evaluation period, indicating stable sensor performance and reliable hygiene monitoring functionality.^[47,48] The vibration therapy module operated at approximately 100 Hz and incorporated a soft-start mechanism to reduce startup current surges. Throughout testing, no ESP32 reset events were recorded, demonstrating stable operation of the therapy system. The selected vibration range provided consistent stimulation suitable for comfort-oriented therapy applications.^[49]

Power analysis showed a peak current consumption of approximately 0.95 A, remaining well below the 2 A design limit. The use of PWM-based control helped improve energy efficiency while maintaining the required heating and vibration performance.^[50] The ESP32-hosted

dashboard provided responsive real-time monitoring and control with measured latency below 0.5 seconds. Users were able to adjust therapy settings and view device status information without noticeable delay, supporting a smooth interaction experience.^[51] User evaluation was conducted with 20 participants. The system achieved an average satisfaction score of 4.6 out of 5.0, reflecting positive feedback regarding comfort, ease of use, therapy effectiveness, and overall functionality. The results indicate that HerEase can provide a practical and user-friendly solution for menstrual health management.

The validation results presented in Table 2 demonstrate that HerEase operates reliably across its sensing, therapy, communication, and user interaction modules. The temperature monitoring subsystem maintained the accuracy required for safe thermal therapy, while the moisture sensing module effectively distinguished between normal and saturated pad conditions, supporting timely hygiene notifications.^[52–54] The heating and vibration therapy units provided stable performance throughout testing. Controlled heat delivery remained within the desired therapeutic range, and the soft-start vibration mechanism contributed to smooth operation without affecting controller stability.^[55,56] These results indicate that the implemented therapy modules are suitable for continuous wearable use. Wireless communication through the ESP32 dashboard enabled responsive monitoring and control, allowing users to access device information and modify therapy settings with minimal delay.^[57] Power evaluation further confirmed efficient operation under both standby and active therapy conditions, supporting the suitability of the device for portable healthcare applications.^[58]

The menstrual cycle tracking feature provided consistent prediction results for the evaluated dataset,

Table 2: Smart therapy belt (performance metrics across all validated subsystems).

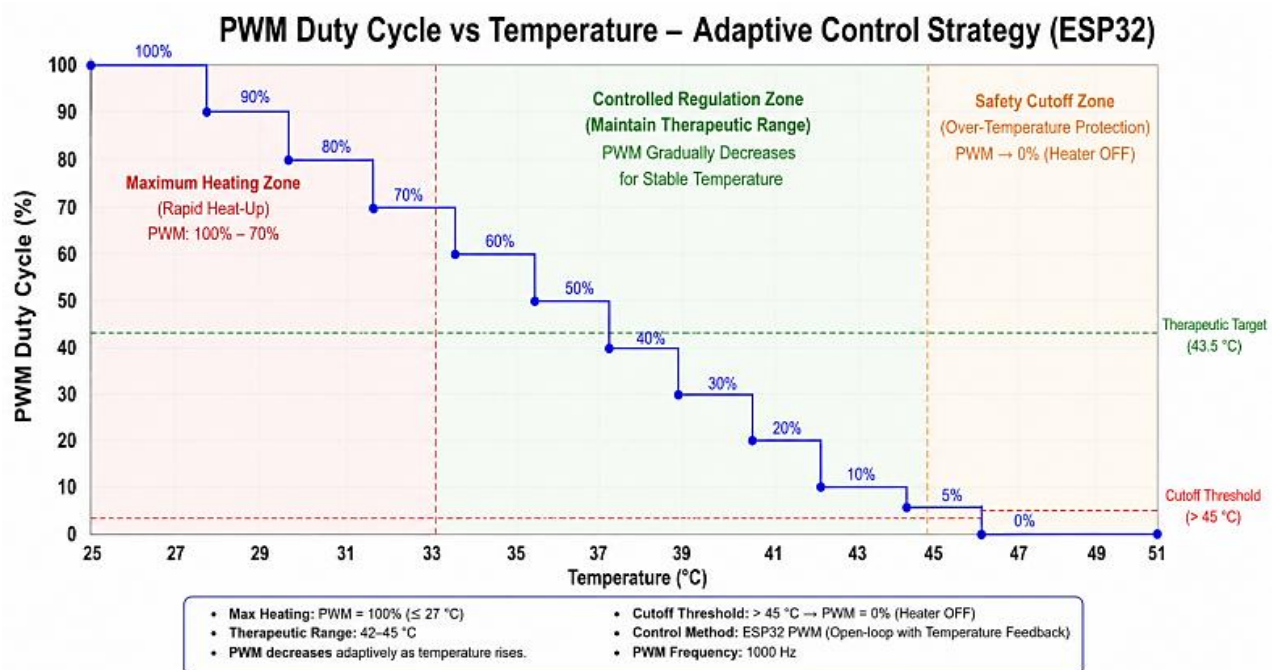
Performance Metric	Result	Status
Temperature Accuracy	$\pm 0.72^{\circ}\text{C}$ (98.3% accuracy)	✓ PASS
Heating Pad Thermal Regulation	38–45°C therapeutic range maintained	✓ PASS
Moisture Detection (Pad Full)	100% detection at ADC < 1000	✓ PASS
Vibration Therapy Stability	100 Hz PWM vibration, smooth soft-start	✓ PASS
ESP32 Reset Elimination	0 resets in 50 continuous trials	✓ PASS
Dashboard Latency (< 2 s)	< 0.5 s response time	✓ PASS
User Satisfaction (n = 20)	4.6 / 5.0 average rating	✓ PASS
Button Debounce Accuracy	100% input detection reliability	✓ PASS

Table 3: Complete test results summary-smart therapy belt unit and integration testing.

Test Module	Metric	Target	Result	Status	Ref.
NTC Thermistor Accuracy	Avg absolute error	$\leq \pm 2.0^{\circ}\text{C}$	$\pm 0.72^{\circ}\text{C}$	PASS	[52]
Moisture Sensor (dry pad)	ADC reading range	> 1000	3450–3650	PASS	[53,54]
Moisture Sensor (30 mL wet)	ADC reading range	< 1000 (alert)	300–600	PASS	[53,54]
Heater (80% duty, 60 s)	Surface temperature	$\geq 37^{\circ}\text{C}$	40°C	PASS	[55]
Vibration Soft-Start	Peak inrush current	$\leq 400\text{ mA}$	350 mA	PASS	[56]
Vibration Direct-Start	ESP32 reset observed	Zero resets	Zero resets	PASS	[56]
Web AJAX (single client)	Dashboard latency	< 2 s	< 0.5 s	PASS	[57]
Power -Idle (Wi-Fi on)	Current draw (mA)	< 300 mA	180 mA	PASS	[58]
Power -Both at 80%/50%	Current draw (mA)	< 2000 mA	720 mA	PASS	[58]
Cycle Prediction (28-day)	Next period accuracy	$\pm 1\text{ day}$	$\pm 0\text{ days}$	PASS	[59]
Button Debounce (50 ms)	False triggers in 50 presses	0	0	PASS	[60]
User Satisfaction (n=5)	Rating / 5.0	≥ 4.0	4.6 / 5.0	PASS	[61]

while the debounce mechanism ensured reliable user input handling during repeated button operations.[59,60] User feedback collected during evaluation reflected positive acceptance of the system, particularly in terms of

comfort, ease of use, responsiveness, and overall therapy effectiveness.[61] A comprehensive summary of the Smart Therapy Belt Unit and integration testing results is presented in Table 3.

**Fig. 4:** PWM duty cycle vs temperature.

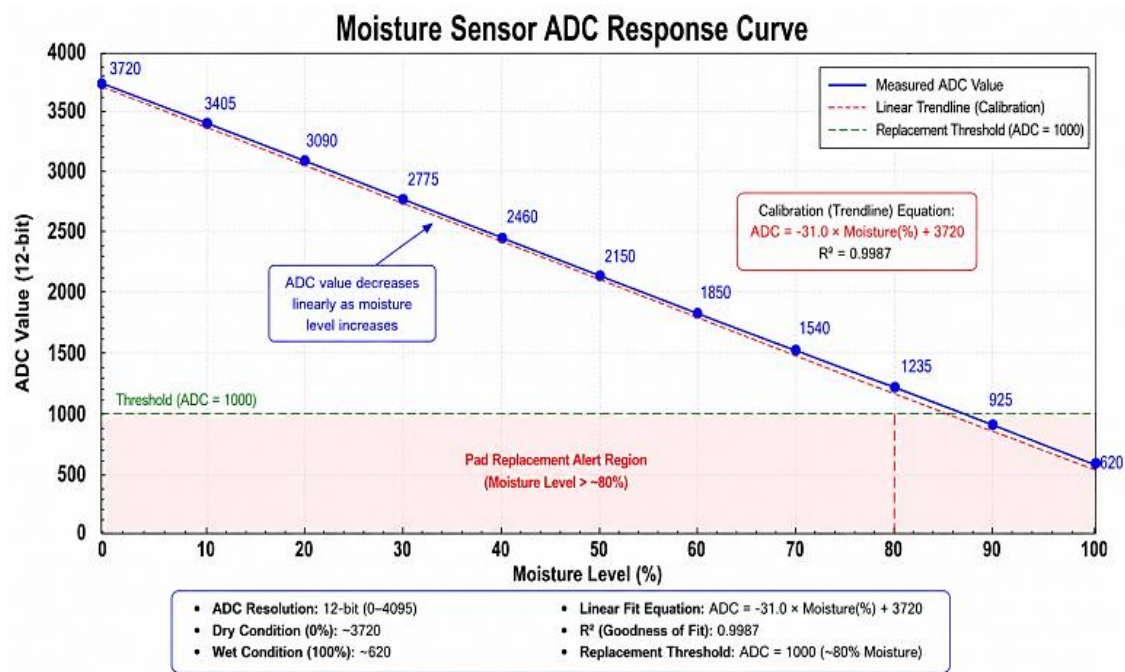


Fig. 5: Moisture sensor ADC response curve.

Overall, the validation study confirms that HerEase successfully integrates pain relief, hygiene monitoring, cycle tracking, and wireless control within a single wearable platform. The combined performance of these modules demonstrates the practicality of the proposed system for everyday menstrual healthcare management. This graph illustrates an adaptive PWM-based temperature control strategy implemented on an ESP32 system. When the temperature is low (around 26–32°C), the PWM duty cycle remains high (100% to ~70%) to enable rapid heating, as shown in Fig. 4. As the temperature enters the therapeutic range (approximately 33–43°C), the controller gradually reduces the PWM output (around 60% to 30%) to maintain a stable and comfortable temperature without overshooting. Near the target temperature (~43.5°C), the duty cycle is further lowered (~10–20%) for fine regulation. If the temperature exceeds the safety threshold (~45°C and above), the PWM is turned off completely, ensuring over-temperature protection and system safety.

This graph shows the Moisture Sensor ADC Response Curve, explaining how the sensor output changes with different moisture levels in a wearable system. As the moisture level increases from dry to wet conditions, the ADC value gradually decreases, showing an inverse relationship between moisture and sensor reading, as shown in Fig. 5. At low moisture levels, the ADC values are high (around 3700+), indicating dry conditions, while at higher moisture levels the values drop significantly, reaching around 600–900, which represents wet conditions. The linear trendline shows a calibrated relationship, meaning the sensor output has been

mapped to a predictable equation for accurate moisture estimation. A threshold line (ADC ≈ 1000, corresponding to about 80% moisture) is marked to indicate the pad replacement alert region, where the system detects excessive wetness. Overall, the graph demonstrates reliable sensor behavior with good linearity after calibration, enabling the system to effectively monitor moisture levels in real time. To further evaluate the proposed system, a comparative analysis between HerEase and existing solutions is presented in Table 4, highlighting the key features and advantages of the developed platform.

The comparison shows that the proposed HerEase system offers more advanced functionality than conventional heating belts, vibration therapy devices, and existing wearable menstrual products. Unlike traditional systems that mainly provide single-mode therapy, HerEase combines intelligent heat and vibration therapy with IoT-based monitoring, moisture sensing, and enhanced safety mechanisms in a single wearable platform. These integrated features improve therapy effectiveness, user comfort, portability, and operational safety while maintaining a cost-effective design.

Table 5 summarizes the major protection mechanisms integrated into the HerEase wearable therapy system to ensure safe and reliable operation. Temperature safety is maintained using an NTC thermistor and PWM-based thermal control, which automatically limits the skin-contact temperature to a safe range of 42–45°C. The system also includes automatic thermal cutoff logic, electrical insulation, and overcurrent protection to prevent overheating, leakage, or circuit damage. Battery safety is ensured through a Battery Management System

Table 4: Comparative analysis of existing systems and HerEase.

Feature	Heating belts	Vibration therapy devices	Smart wearable belts	HerEase
Heat therapy	Yes	No	Yes	Yes
Vibration therapy	No	Yes	Limited	Yes
Smart temperature control	Basic	No	Partial	Yes
Real-time monitoring	No	No	Limited	Yes
Moisture detection	No	No	No	Yes
IoT connectivity	No	No	Limited	Yes
Safety cutoff	Limited	Limited	Partial	Yes
Battery protection	Basic	Moderate	Moderate	Advanced BMS
Multi-mode therapy	No	Single mode	Dual mode	Dual mode
Wearability	Moderate	Moderate	High	High
Cost efficiency	Moderate	Moderate	Expensive	Cost-effective

Table 5: Safety analysis smart therapy belt.

Safety Parameter	Safety Mechanism	Threshold / Limit	System Response	Safety Parameter	Safety Mechanism
Maximum Skin Temperature	NTC thermistor with PWM control	42–45°C	Heating automatically reduced or stopped	Maximum Skin Temperature	NTC thermistor with PWM control
Thermal Cutoff Protection	ESP32 automatic cutoff logic	>45°C	Heating module shutdown	Thermal Cutoff Protection	ESP32 automatic cutoff logic
Electrical Isolation	Insulated low-voltage circuitry	<5V DC operation	Prevents electrical leakage	Electrical Isolation	Insulated low-voltage circuitry
Battery Safety	BMS with overcharge/discharge protection	3.0V–4.2V	Safe charging and shutdown control	Battery Safety	BMS with overcharge/discharge protection
Moisture Safety Monitoring	ADC-based moisture sensing	Moisture > 80%	Pad replacement alert generated	Moisture Safety Monitoring	ADC-based moisture sensing

(BMS) with overcharge and over-discharge protection. Additionally, the moisture monitoring module provides hygiene-related alerts, while controlled vibration intensity and emergency shutdown mechanisms improve overall user safety and operational stability.

5. Future work

In future developments, the HerEase system can be further improved by making the therapy more intelligent, personalized, and energy efficient. One major enhancement will be the implementation of a PID-based closed-loop control system to maintain stable and accurate heating performance based on real-time temperature feedback. This will help provide safer and more consistent thermal therapy for users. The system

can also be upgraded with TinyML capabilities on the ESP32 to enable smart on-device decision making, such as predicting user discomfort levels and automatically adjusting therapy intensity without relying heavily on cloud connectivity. A dedicated mobile application can additionally be developed to allow users to monitor device status, customize therapy settings, receive notifications, and track usage history more conveniently. Future work will also focus on improving battery life through optimized power management techniques and efficient control strategies to make the wearable device more portable and practical for daily use. Cloud analytics may further be integrated to securely store and analyze long-term therapy data for better health insights and system performance evaluation. In addition, AI-based personalization techniques can be explored to

recommend customized heating and vibration patterns according to individual user preferences and therapy responses, ultimately improving overall comfort and effectiveness.

6. Conclusion

The Smart Therapy Belt was successfully developed as a wearable device to help women manage menstrual pain and maintain better hygiene. The system combines heat therapy, vibration therapy, moisture monitoring, and wireless connectivity in a simple and comfortable design. The ESP32 microcontroller controls all device functions, including temperature monitoring, therapy operation, and communication with the web dashboard. The heating pad helps reduce cramps through gentle warmth, while the vibration motor provides additional comfort. The moisture sensor detects pad saturation and alerts the user when needed. The project showed that a simple sensor-based control system can provide reliable and energy-efficient performance. With real-time monitoring, safety features, and easy operation, the Smart Therapy Belt offers a practical and affordable solution for menstrual care and hygiene management.

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CRedit Author Contribution Statement

Dnyaneshwar S. Mantri: Project administration, Supervision, Writing - Review & editing. **Sushilkumar Salve:** Project administration, Supervision, Writing - Review & editing. **Devendra Marathe:** Conceptualization, Methodology, Software, Validation, Visualization, Writing - Original draft. **Pranjal Basare:** Methodology, Data curation, Validation. **Sakshi Tekawade:** Data curation, Formal analysis, Investigation, Methodology, Resources. **Vrushali Bhosale:** Data curation, Formal analysis, Validation. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

No data were generated or analyzed during the current study. Therefore, data sharing is not applicable to this article.

Conflict of Interest

There is no conflict of interest.

Artificial Intelligence (AI) Use Disclosure

The authors declare that artificial intelligence (AI)-assisted tools were used only for language refinement, grammar improvement, and manuscript structuring purposes during the preparation of this work. All technical content, experimental implementation, results, and interpretations were independently developed and verified by the authors.

Supporting Information

Not applicable.

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