Sootra: A Personalised Smart Menstrual Pain Relief Band

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Abstract—**Menstrual pain is a common health complaint that interferes with daily activities and reduces quality of life. Because of that fact, there has been an ever-growing demand for accessible, personalised, and non-pharmacological pain relief. Sootra introduces a novel, user-centred approach toward intelligent menstrual pain relief in the form of adaptive heat therapy with precision vibration massage. Equipped with smart sensors on board, it keeps monitoring the user's level of discomfort and physiological responses continuously, thus automatically adjusting temperature and massage intensity for personalised pain management. Complementary is a mobile application where users can set desired therapy modes, monitor menstrual health patterns, and receive AI-driven guided insights into their well-being. Sootra marries data-driven personalisation to time-tested therapeutic techniques, hence offering safe, portable, and medication-free ways of dealing with menstrual pain so as to make users feel comfortable, autonomous, and well along their menstrual cycle.**

Index Terms—**Menstrual pain, smart wearable, adaptive heat therapy, vibration massage, personalized health**

I. INTRODUCTION

While menstruation is a very normal biological process, it causes a lot of distress for most women. In fact, menstrual cramps are generally considered one of the major issues that come forth with menstruation. More than half of menstruating women experience mild to extreme painful cramping that stops them from continuing their day-to-day activities. A lot of lady's experience 2-3 days every month when the regular activity becomes so hard that they often need to miss school, work, and social events just because the pain is simply extreme. Despite being prevalent, menstrual cramps are an under-discussed topic, and most solutions that do exist fall short for those afflicted.

Traditional methods of treating menstrual pain generally included over-the-counter medication and heating pads. While these treatments may help alleviate symptoms, medications have adverse effects, and heating pads cannot deliver constant, concentrated, and sustained heat in the lower abdomen. These shortcomings indicate a need for an efficient, feasible, and user-friendly remedy. An innovative pain-relieving tool called a period massager with integrated heat therapy was developed to close this gap. This innovation aims to treat menstrual cramps by applying controlled heat and a mild vibration massage to the lower abdomen, which is the main cause of this type of discomfort. While the heat therapy improves blood flow, relaxes the uterine muscles, and reduces the force of spasmic contractions, the massages reduce muscle tension and ease spasms.

The massager provides heating controlled at an optimum temperature of 30°C-33°C, the temperature that minimises burns while ensuring comfort. This temperature is constantly maintained through the temperature sensor LM35, hence operating it within the limits of safety and stability. Heating therapy in a period massager has combined therapeutic effects, offering a practical and non-pharmacological holistic approach to menstrual discomfort management.

II. LITERATURE REVIEW

The study presented in the paper [1] proposes a programmable dual-mode implantable PRF stimulator that not only offers the capacity of wireless energy transfer but also the modes of voltage and/or current stimulation, in addition to a temperature sensing facility. Also, a study on the effectiveness of the device is presented on a rat model of trigeminal neuralgia. The results have proved a remarkable reduction in pain levels up to 14 days, reduced nerve overactivity, no apparent damage to the tissue, and better performance compared to traditional drug therapy.

The authors in [2] adopted an approach by using infrared temperature measurement and computer-based bioheat simulation techniques to evaluate moxibustion's mechanism for raising the tissue temperature. It was observed that the moxa stick may reach a temperature close to 500 °C, creating zones of varying temperatures. It was also observed that the temperature may rise up to 12 mm from the skin surface. Variables affecting the temperature distribution included the loss due to radiation and the evaporation of moisture. A distance of 3 cm would give a surface temperature of approximately 50 °C without burns.

The authors in [3] reviewed wearable devices designed to predict epileptic seizures using EEG signals. Their discussion included signal collection, noise removal, extraction of time- and frequency-based features, and classification using methods like SVM, CNN, and Random Forest. They found that the most implemented method was SVM, while a mobile multimedia framework achieved the best accuracy of 99.02%.

The authors in [4] designed a wearable-based primary healthcare system that continuously records vital signs, processes data, extracts useful features, applies machine learning for prediction, calculates the risk scores, and displays the results in a visual format. The framework improved early detection of health problems, increased accuracy of monitoring, supported better clinical decisions, aided chronic disease care, and enhanced nursing education through practical data-driven training.

The authors in [5] designed a neck-worn device that provided thermal comfort using Peltier modules controlled according to a heart rate variability-related algorithm run on a smartphone and derived from PPG signals. The device was effective over a 28–38 °C range when worn and in controlled tests successfully predicted user comfort. However, it demonstrated limited cooling power, issues with motor heating, and reduced accuracy for fast-changing temperature sensations.

The study in [6] developed a wireless heating e-textile belt with Bekinox threads, divided into four independently controlled conductive sections. It included LM35 sensors, a BLE microcontroller, and PID-based PWM for maintaining temperatures between 33°-44 °C. During ten 30-minute trials at 44 °C, the system exhibited an extremely low average error of 0.029 °C ($t=2.2130 < 2.262$), thus establishing the reliability of temperature regulation.

An IoT-based GPS Wearable Band using ESP32 controller, 50m Geofencing, Cloud connectivity, and Anti-Tamper mechanism was proposed by the authors in [7], to monitor the quarantined COVID-19 patients. Accuracy up to 2.5m in real-time tracking, immediate alert on boundary violation, 14-day battery life using a 500mAh Li-Po rechargeable battery, and low cost of implementation around ₹1600.

In the research conducted by the study in [8], it designed an IoT system of "Real-Time Health Monitoring Using ESP32 & Node MCU with ECG, SpO2, Temperature, Humidity, Pulse, and Gyroscope Sensor." The described IoT smart system collected data from the sensors, filtered the data, sent alerts whenever the sensor signals exceeded the limits, and sent data to the UBIDOTS cloud platform as required. The IoT system ensured precise monitoring, smooth data transmission, correct display on the dashboard, and appropriate alarms being generated.

The work carried out by the authors in [9] presented a multimodal mobile health system that involved activity tracking, sound analysis, facial expressions, and self-reports to create a continually measured feedback system. Through the use of various algorithms like HMM, GMM, and SVM, and various system designs like SAINT and Life Streams, the system promoted stress monitoring, mobility monitoring, personalization, and long-term monitoring and management of chronic pain.

The study in [10] presented a low-cost motion tracking system consisting of just one IR-filtered camera and a corresponding 9-axis IMU device, along with two external markers illuminated by LEDs. A sophisticated sensor fusion algorithm running in real time is implemented for computing the 3D position and orientation of the device using a microcontroller. An accuracy of 3.28 cm position and 0.89 degrees orientation was obtained at speeds of more than 20 frames per second.

The authors in [11] also proposed a cost-effective contact tracing device using ATmega328P, NRF24L01 communication protocol, and NTC thermistor, which includes features for averaging temperature, sending secure IDs within a distance of 6 feet, providing trend time memory, uploading to clouds, comparing it with official records, and sending messages to infected users.

The study in [12] presented the work on a polyurethane foam vibration sensor used for monitoring faults on a three-phase induction motor. Under firm mounting conditions, 1 kHz sampling rate, and using an FFT technique in comparison with an ADXL335 accelerometer, the study showed that the sensor was sensitive to low frequency and detected sub-harmonics, with distinct harmonic responses according to the position of the sensor for fault detection.

The authors in [13] have introduced a two-part IoT-based system that helps relieve pain from varicose veins. A thermistor-based system monitors the temperature of the upper portion of the body, while the other module monitors the temperature of the legs compared to a fixed limit. If abnormal levels of temperature differences are detected, there are vibration motors that operate to relieve the pain.

The study in [14] proposed an ESP8266-based device to provide relief from menstrual pain by using vibration therapy, controlled heating (30-33 °C) through an LM35 sensor, and aromatherapy using Blynk IoT. The authors implemented five working modes to monitor the parameters in real-time. The device was tested with 20 subjects, and the combined mode was the most preferred option to ensure pain relief in the safest manner.

The authors in [15] have devised a programmable Arduino-based TENS machine to implement myotonia congenita treatment as well as to handle the associated spasm conditions without surgery. The machine produces monophasic PWM with a frequency range of 1 to 125 Hz at a 50% duty cycle, amplifies the signals using LM741 op amps, and limits the current to 2.2 mA for safety purposes. With ten subjects participating in trials, 80% reduction in pain has been achieved.

In the paper by reference [16], an IoT wind gate system for monitoring via a force sensing resistor and a pulse sensor connected to Arduino with cloud support, MQTT was proposed. With 40 volunteers and 160 measurements, an average error of 2.21% was attained for the system as compared to another device for accurate Thai massage training.

A flexible adhesive strain sensor was developed by the authors of [17] using a PVDC-co-VC/PSS-CNT nanocomposite with a PSA layer and copper contacts. A stable gauge factor of 15 ± 1 over 16 cm was achieved at 2 wt.% concentration near the percolation point, showing uniform material distribution, dependable strain detection, and suitability for IoT wearable applications.

The study in [18] introduced a low-power wearable healthcare system incorporating flexible sensors, edge AI processing, and smart energy management. Near energy-neutral operation was obtained by investigating energy harvesting from light, motion, radio waves, and body heat. These results demonstrate that continuous monitoring is capable, battery use is lower, comfort is improved, and suitability for personalized home healthcare is enhanced.

III. METHODOLOGY OF PROPOSED SYSTEM

A. Hardware Requirement:

1. ESP32 DevKit V1: low-cost Wi-Fi and Bluetooth-enabled micro-controller board based on the ESP32 chip.
2. Peltier Module: It controls temperature actively. It cools or heats the depending upon its thermoelectric property.
3. Vibration motor: A small DC motor that creates vibration by using an unbalanced weight.
4. 3S Li-ion battery: A battery consisting of 3 lithium-ion cells connected in series, offering a nominal voltage of 11.1V (12.6V fully charged).
5. Buck converter: A DC-DC step-down converter that converts a higher voltage (such as 12V) to a lower stable voltage (such as 5V or 3.3V).
6. Motor driver: An electronic circuit that controls the speed and direction of a motor by supplying the necessary current and voltage from a microcontroller.
7. Relay: A relay is an electrically operated switch that is used to control a high-power circuit with a low-power signal.

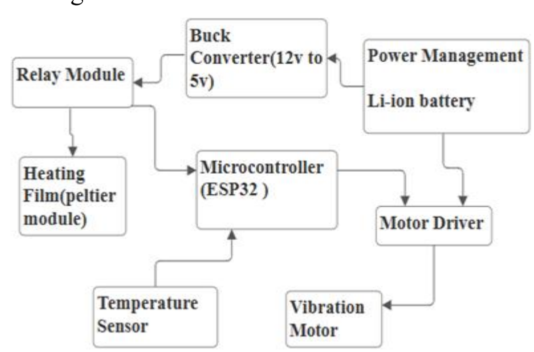


Figure 1 shows Block Diagram of Proposed System.

B. Mobile Application

The Sootra system is connected with a specialised mobile application that aims to deliver an optimal user interface for the wearable system's operation and monitoring. The mobile application allows wireless connectivity with the wearable system using both Wi-Fi and

Bluetooth technologies. This allows the Sootra wearable system to operate flexibly in any environment. Furthermore, the mobile application allows users to configure the intensity of the heated surfaces using an interactive slider bar option. This allows users to control the temperature level provided by the Peltier element with maximum precision. In addition, the mobile application features special therapy modes such as Low, Medium, and High that offer the ability to quickly change the temperature setting within the safe temperature limits of the Sootra wearable system. An independent toggle option for the vibration motor is also available with the mobile application, which allows users to modify the level of therapy according to their comfort level. Furthermore, the temperature level is also available as an option with the mobile application's interface to help users remain safe around the Sootra wearable system. A timer option is also available with the mobile application that allows users to schedule the operating time of the Sootra wearable.

C. Flowchart

Figure 2 shows the operational flow of the proposed Sootra smart pain relief system. The system, once powered on, initialises the mounted hardware: the ESP32 microcontroller, temperature sensor, Peltier module driver circuitry, vibration motor driver, and communication modules. This initialisation of peripherals by the controller ensures that all are functioning correctly and that the base temperature readings are stable enough to begin safe operation.

Once it has finished initialising, the system grants wireless communication via Wi-Fi or Bluetooth to enable synchronisation with the mobile application. Once connected, the device goes into an idle state where both the Peltier heating module and the vibration motor are off by default. The system then waits for user input via a mobile application. The user chooses the desired settings for therapy: the intensity of heating by using a slider or preset modes Low, Medium, and High, the turning on of the vibration motor, and the session timer duration. This information is sent to the ESP32, which will process the received commands by providing appropriate PWM signals to drive the Peltier module through a switching circuit of the MOSFET type. At the same time, the vibration motor will be turned on if requested by the user.

During operation, the integrated temperature sensor of the system continuously monitors the surface temperature. Real-time temperature data is processed and matched against a predefined safe operating threshold of 45°C. If the temperature still remains within the safe therapeutic range, then the device keeps operating normally. If the temperature rises above 45°C, the controller instantly turns off the Peltier module and the vibration motor, putting the device into safety shutdown mode to avoid overheating or causing discomfort. Meanwhile, the session timer is continuously checked. After the session duration of the therapy is completed, all running components automatically go into an 'off' mode and, by default, revert to idle mode. The device will remain prepared for any subsequent session, unless manually powered off by the user. This systematic flow of control guarantees safe, reliable, and effective therapeutic operation.

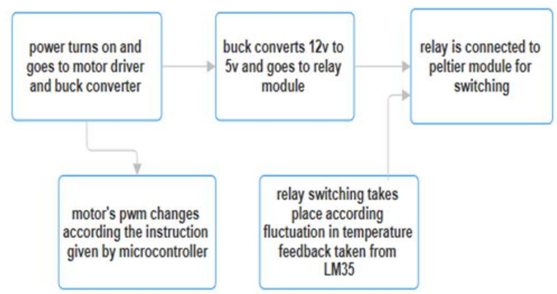


Fig. 2. Flow Diagram of System.

IV. RESULTS AND DISCUSSIONS

The Sootra smart menstrual pain relief system, proposed for use in relieving menstrual pain, was subject to experimental evaluation in terms of thermal performance, safety and reliability, user comfort, and overall functional efficiency of the product. The findings are presented briefly below, organized into four main subsections: the thermal regulation performance, the safety and protection features, the user interface efficiency, and the overall therapeutic efficiency.

A. Thermal Performance and Temperature Regulation

For instance, the system was tested and implemented under different working conditions, such as the "Low" mode, equivalent to around 38°C, "Medium," equivalent to around 42°C, and "High," equivalent to around 45°C. For a Peltier module regulated by a series of pulse width modulation control signals produced by the ESP-32, the temperature output consistently provided within a range of therapeutic temperatures was ensured through the use of the temperature sensor, indicating a temperature equilibrium with minimal variability of only ±1.5°C.

In Low mode, stabilization occurred at 37.8-38.5 degrees C. In this mode, mild heat was benefited. In Medium mode, a temperature range between 41-42.5 degrees C was achieved. It was reported to offer considerable pain relief within 10-15 minutes of usage. In contrast, in High mode, stabilization was achieved at 44-45 degrees C. It was applicable for short periods of use. The automatic cutoff feature successfully switched off the Peltier module and the vibration motor when the temperature was above 45 degrees C.

From the battery discharge tests, it has been observed that during moderate PWM operation, i.e., at around 40 to 50 percent duty cycles, the system could run with an operational interval.

B. Safety and Protection Mechanisms

Because the device was worn, system evaluation had to be supported by safety validation. For this purpose, a 3S BMS on the test setup prevented overcharge, over-discharge, and short-circuit conditions throughout testing. Voltage levels in every charge-discharge cycle never went out of the safety operation area.

Thermal protection has been evaluated by artificially increasing the load on the Peltier module to simulate their potential overheating conditions. Once the sensed temperature exceeded the preset threshold of 45°C, ESP32 immediately cut both heating and vibration outputs. The shutdown response time was less than one second, pointing toward reliable and fast protective action.

Also, the timer-based auto-shutdown successfully sent sessions into termination in their entirety after a certain length of time, ensuring minimal risk of long-term exposure and battery drain. All these combined hardware and software safety features have ensured dependable system protection during continuous operation.

C. User Interface and Accessibility

The interface design of the mobile application was tested regarding its responsiveness, ease of use, and effectiveness in terms of reliable communication. The Wi-Fi and Bluetooth connectivity modes were also tested. Bluetooth proved useful for connectivity without the need for internet accessibility, although Wi-Fi ensured remote capabilities. Users managed to adjust heat intensity using the slider method and configure the predefined modes of therapy. The vibration motor switch is done independently to allow for a combination of therapies. The real-time displays of percentage and temperature-built confidence in the user.

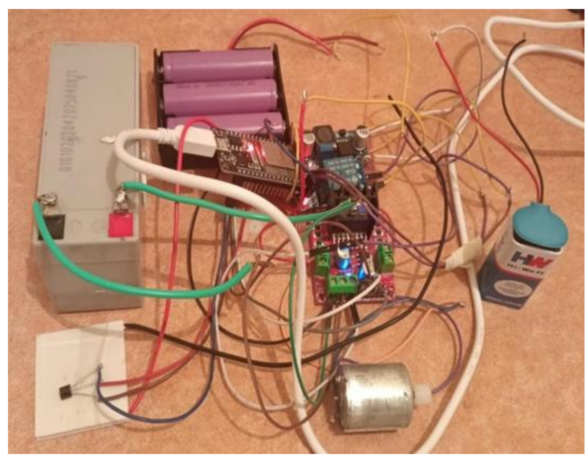
The timer function was also seen to be effective, automatically terminating the sessions at the set time. Generally, the application interface was seen to be intuitive, thereby requiring no technical knowledge, making it accessible for use by many users.

D. Therapeutic Effectiveness and Practical Impact

First user tests showed that there were notable reductions in menstrual pain after 15-20 minutes of usage on medium mode. The controlled heat therapy and vibration stimulation have a cumulative effect that enabled better relaxation of the muscles and better blood flow around the abdominal area.

The compact nature of the belt ensured proper contact between the Peltier surface and the body, thereby ensuring comfort. Insulation and fabric ensured comfort during the long hours of wear without any irritation.

V. EXPERIMENTAL SETUP



VI. CONCLUSION

The Sootra project represents a novel innovation in the management of menstrual cramps by developing a product to relieve pain through the use of wearable technology with embedded electronics. The Sootra solution intends to give users the ability to select from a variety of ways to relieve discomfort based upon their own comfort and pain threshold. Sootra has combined real-time monitoring with the delivery of treatments (heat/vibration) in a user-specific manner to provide a unique pain relief experience to each user, providing each user with confidence that their treatments are delivered at an effective level based upon the user's comfort and pain tolerance level. Sootra has also established that the temperature of its devices will always be maintained within a safe range, based on empirical data collected from the past performance of each device. The current Sootra prototype is designed to provide users only with the ability to relieve pain; however, we intend to develop future prototypes with machine learning capabilities, enabling us to provide users with adaptive therapies and/or to analyse long-term health data and use real-time monitoring data to enhance their quality of life through the use of Sootra products.

REFERENCES

[1] K. Y. Yeh et al., "A dual-mode multifunctional pulsed radio-frequency stimulator for trigeminal neuralgia relief and its animal model," IEEE Transactions on Biomedical Circuits and Systems, vol. 15, no. 4, pp. 719–730, Aug. 2021. DOI: 10.1109/TBCAS.2021.3097058.

[2] Y. Li et al., "An in vitro and numerical study of moxibustion therapy on biological tissue," IEEE Transactions on Biomedical Engineering, vol. 65, no. 4, pp. 779–788, Apr. 2018. DOI: 10.1109/TBME.2017.2719633.

[3] P. Kaur, V. Bharti, and S. Maji, "Comparison of machine learning approach in smart wearables," in Proc. Women Institute of Technology Conf. on Electrical and Computer Engineering (WITCON ECE), Dehradun, India, 2019, pp. 135–138. DOI: 10.1109/WITCONECE48374.2019.9092921.

[4] L. Zhang, "Data analysis and teaching model construction of smart wearable devices in primary care monitoring," in Proc. 3rd Int. Conf. on Data Analytics, Computing and Artificial Intelligence (ICDACAI), Zakopane, Poland, 2024, pp. 686–690. DOI: 10.1109/ICDACAI65086.2024.00130.

[5] G. Lopez, K. Takahashi, K. Nkurikiyeyezu, and A. Yokokubo, "Development of a wearable thermo-conditioning device controlled by human factors based thermal comfort estimation," in Proc. 12th France-Japan and 10th Europe-Asia Congress on Mechatronics, Tsu, Japan, 2018, pp. 255–259. DOI: 10.1109/MECATRONICS.2018.8495727.

[6] R. Yrureta, M. V. Caya, and W. Y. Chung, "Development of wireless heating e-textile belt for thermotherapy application with four quadrant control," 2020, pp. 1–6. DOI: 10.1109/HNICEM51456.2020.9400129.

[7] G. Singh, M. Singh, S. Dhall, P. Bhateja, K. Sharma, and R. Kaur, "GOCO wearable tracker band for COVID-19 patients," in Proc. Int. Conf. on Advanced Technologies in Mechatronics, Electrical and Computer Engineering (ICATME), 2021, pp. 306–310. DOI: 10.1109/ICATME50232.2021.9732709.

[8] S. L. Neeraja, T. V. Kishore, U. Deepika, S. Prathyusha, and V. K., "IoT-enabled advanced health monitoring system using ESP32 and UBI DOTS," in Proc. Int. Conf. on IoT Based Control Networks and Intelligent Systems (ICICNIS), Bengaluru, India, 2024, pp. 403–408. DOI: 10.1109/ICICNIS64247.2024.10823147.

[9] M. S. H. Aung et al., "Leveraging multi-modal sensing for mobile health: A case review in chronic pain," IEEE Journal of Selected Topics in Signal Processing, vol. 10, no. 5, pp. 962–974, Aug. 2016. DOI: 10.1109/JSTSP.2016.2565381.

[10] M. P. Wilk, M. Walsh, and B. O'Flynn, "Low cost embedded multimodal opto-inertial human motion tracking system," in Proc. 31st Irish Signals and Systems Conf. (ISSC), Letterkenny, Ireland, 2020, pp. 1–6. DOI: 10.1109/ISSC49989.2020.9180190.

[11] V. Joseph, S. K. Souparnika, and S. Haridas, "Low-cost wearable device to provide an effective solution for contact tracing and logistics," 2023, pp. 1–4. DOI: 10.1109/ICONAT57137.2023.10080852.

[12] S. Asutkar, D. Gupta, and S. Tallur, "Machine health monitoring using a novel low cost elastomer based vibration sensor," in Proc. Joint Conf. of the IEEE Int. Frequency Control Symposium and European Frequency and Time Forum (EFTF/IFC), Orlando, FL, USA, 2019, pp. 1–2. DOI: 10.1109/FCS.2019.8856118.

[13] N. Ananthi, B. Monish, M. Madhummitha, and P. Kirthika, "Smart pain relief device for varicose veins using IoT & Arduino," 2023, pp. 349–354. DOI: 10.1109/ICESC57686.2023.10193480.
[14] M. A. Joseph, S. Jacob, S. A. Nair, A. R. S., and A. R. V., "Soothing relief for menstrual cramps: A period massager with heat therapy and aromatherapy," in Proc. Emerging Technologies for Intelligent Systems (ETIS), Trivandrum, India, 2025, pp. 1–5. DOI: 10.1109/ETIS64005.2025.10961477.
[15] N. Krishna, A. Dikshit, and R. Preran, "TENSify: A therapeutic approach towards myotonia congenita," in Proc. 4th Int. Conf. on Data Engineering and Communication Systems (ICDECS), 2024, pp. 1–5.
[16] C. Kamyod and P. Hongsing, "The proposed wind-gate monitoring system for teaching and learning Thai traditional massage," 2023, pp. 353–356. DOI: 10.1109/ECTIDAMTNCON57770.2023.10139348.
[17] V. Sankar, K. Balasubramaniam, and S. Ramaprabhu, "User-centric design: Flexible strain sensor adhesive tape," in Proc. IEEE Int. Conf. on Flexible and Printable Sensors and Systems (FLEPS), Boston, MA, USA, 2023, pp. 1–4. DOI: 10.1109/FLEPS57599.2023.10220380.
[18] T. Basaklar, Y. Tuncel, S. An, and U. Ogras, "Wearable devices and low-power design for smart health applications: Challenges and opportunities," 2021, pp. 1–1. DOI: 10.1109/ISLPED52811.2021.9502491.