RESEARCH PAPER

Intelligent Thermal And Vibration Therapy For Chronic Venous Disease

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Abstract

Chronic venous disease (cvd) is a common condition characterized by poor blood circulation in the lower limbs, leading to discomfort, swelling, and long-term complications. This project presents an intelligent, wearable thermal and vibration therapy device designed for home-based management of cvd. The device integrates a ds18b20 temperature sensor for real-time leg temperature monitoring and pressure sensors to detect swelling or abnormal pressure in the lower limbs. The esp8266 microcontroller processes sensor data to automatically regulate therapy. Controlled thermal therapy is provided by a peltier module, delivering precise heating or cooling to improve blood circulation, while vibration motors stimulate blood flow and reduce discomfort. An lcd display offers continuous feedback on temperature, pressure, and therapy status, enhancing patient awareness and engagement. The device is compact, portable, and fully automated, enabling continuous, personalized therapy at home. This system demonstrates the potential of combining thermal and vibration therapy with intelligent monitoring to improve the quality of life for individuals with chronic venous disease. Chronic venous disease (cvd) affects millions worldwide, causing leg pain, swelling, and reduced quality of life due to impaired blood circulation. Conventional therapies often require clinical visits, limiting continuous care. This project introduces an intelligent, wearable device for thermal and vibration therapy, designed for home use to provide continuous, personalized treatment. The system incorporates a ds18b20 temperature sensor for real-time monitoring of leg temperature and pressure sensors to detect abnormal swelling, enabling timely intervention. An esp8266 microcontroller processes sensor data to control a peltier module, delivering precise heating or cooling, and vibration motors that stimulate blood flow and alleviate discomfort. The lcd display provides immediate feedback on therapy status, temperature, and pressure, enhancing patient engagement and safety.

Keywords: Chronic Venous Disease, Wearable Therapy Device, Thermal Therapy, Vibration Therapy, Peltier Module, Ds18b20 Temperature Sensor, Pressure Sensor, Esp8266 Microcontroller, Lcd Display, Blood Circulation, Home-Based Healthcare, Automated Therapy, Patient Feedback, Portable Device, Multimodal Therapy.

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I. Introduction

Chronic Venous Disease (CVD) is a prevalent circulatory disorder that affects a significant portion of the global population, particularly the elderly and individuals with sedentary lifestyles. It arises due to improper functioning of the venous valves in the lower limbs, resulting in poor blood return to the heart. This condition manifests through various symptoms such as swelling, heaviness, fatigue, discomfort, skin discoloration, and in severe cases, venous ulcers. These symptoms not only affect physical health but also limit mobility, reduce quality of life, and increase dependence on healthcare services. Traditional treatment methods for CVD, including medications, compression therapy, and clinical interventions, often require repeated hospital visits and continuous monitoring, which can be inconvenient, costly, and time-consuming. Moreover, these conventional therapies may not always provide immediate relief or personalized treatment, leaving patients with persistent discomfort and reduced compliance. Advancements in wearable technology and smart healthcare systems have opened new avenues for home-based therapeutic solutions that are both effective and patient-friendly. This project focuses on developing an intelligent,

wearable device designed to provide continuous thermal and vibration therapy for the lower limbs, aiming to improve blood circulation, reduce swelling, and alleviate discomfort associated with CVD. The system employs DS18B20 temperature sensors to continuously monitor leg temperature and pressure sensors to detect abnormal swelling or pressure changes in real time. These sensor readings are processed by an ESP8266 microcontroller, which intelligently regulates therapy by controlling a Peltier module for precise heating or cooling and activating vibration motors to stimulate blood flow and reduce discomfort. The inclusion of an LCD display allows patients to receive real-time feedback regarding temperature, pressure, and therapy status, enhancing awareness and engagement in their treatment process. The wearable device is designed to be compact, lightweight, and portable, making it suitable for daily home use by patients of all ages, including the elderly and those with limited mobility. Its automated and adaptive nature ensures that therapy is personalized according to the patient's current condition, eliminating the need for constant clinical supervision. By integrating real-time sensing, automated control, and multimodal therapy, the system addresses the limitations of conventional CVD treatments and empowers patients to manage their condition effectively. Furthermore, this project highlights the growing potential of combining medical devices, microcontrollers, and smart sensors to create innovative solutions in home healthcare. The proposed wearable device not only provides immediate symptomatic relief but also promotes long-term circulation improvement, patient independence, and overall quality of life. By leveraging intelligent monitoring and therapeutic interventions, this project contributes to the development of next-generation home-based healthcare systems that are both accessible and effective for managing chronic venous disease.

II. Literature Survey

Chronic Venous Disease (CVD) is a common condition causing poor blood circulation, leg swelling, pain, and discomfort. Traditional treatments such as medications, compression stockings, and surgeries often require frequent clinical visits and long-term supervision. Thermal therapy has been shown to improve blood flow by heating or cooling the affected area, while vibration therapy helps stimulate circulation and reduce discomfort. Recent studies highlight the use of wearable devices equipped with temperature and pressure sensors for real-time monitoring of leg conditions. Microcontrollers like ESP8266 allow automation and intelligent control of therapy based on sensor readings. Portable, home-based devices improve patient compliance and reduce dependency on hospital visits.

A. IoT-Based Monitoring and Prevention System for Varicose Veins

This paper by S. Ramesh et al., 2023 focuses on developing an IoT-based system for continuous monitoring and prevention of varicose veins. Sensors continuously collect data on temperature, pressure, and other physiological parameters from the lower limbs. The microcontroller processes this data using predefined threshold values to identify abnormal vein conditions. When abnormalities are detected, the information is transmitted to a cloud platform for real-time monitoring. Users receive instant alerts and notifications, allowing them to take preventive actions early. The system is designed for home-based care, reducing dependency on frequent hospital visits. Real-time monitoring ensures timely intervention and improved patient safety. The device promotes proactive management of vein health. It enhances patient engagement through continuous feedback. Data visualization on an IoT dashboard supports tracking and analysis of trends. The automated system ensures consistent and personalized care. Overall, it demonstrates the integration of IoT for intelligent vascular health management.

B. Smart Wearable Device for Varicose Veins Management

This paper by P. Meena et al., 2023 presents a smart wearable device to manage varicose veins effectively. The device is embedded with sensors that continuously monitor leg pressure and pain-related parameters. Data collected by these sensors is processed by a microcontroller to detect abnormal vein behavior. Based on predefined conditions, therapeutic actions such as vibration or localized stimulation are automatically activated. This allows continuous, home-based therapy without constant clinical supervision. Alerts and feedback are provided to improve patient awareness and compliance. The wearable device ensures personalized treatment according to real-time physiological data. It reduces patient discomfort and promotes proactive care. The system is portable and user-friendly for everyday use.

C. Varicose Veins Treatment Using Automated Stockings

This paper by K. Senthamil Selvan et al., 2023 focuses on automated compression stockings for treating varicose veins. The stockings are equipped with sensors that continuously monitor leg pressure and venous blood flow. The microcontroller processes sensor data to automatically adjust compression levels according to predefined thresholds. This ensures optimal blood circulation and reduces discomfort in the lower limbs. Real-time monitoring provides immediate feedback to the patient. The device supports home-based care, minimizing hospital visits. Personalized compression therapy enhances treatment effectiveness and patient comfort. Alerts and notifications help users respond to abnormal vein

conditions. The wearable system is lightweight, user-friendly, and suitable for continuous daily use.

D. Smart Pain Relief Device for Varicose Veins using IoT & Arduino

This paper by N. Ananthi et al., 2023 proposes a smart wearable device for pain relief in varicose vein patients. Sensors embedded in the device monitor pressure, pain, and other leg conditions continuously. The Arduino microcontroller processes this data to identify abnormal vein behavior or discomfort levels. Based on predefined conditions, therapeutic actions such as vibration or localized heating are automatically triggered. The system supports continuous home-based care, reducing the need for hospital visits. Real-time feedback improves patient engagement and confidence in self-management. Personalized therapy ensures timely and effective interventions. Alerts notify users when abnormal conditions are detected. The device is portable, lightweight, and user-friendly. Continuous monitoring promotes proactive healthcare. Integration of IoT and automation demonstrates the feasibility of smart wearable therapy.

E. Early Detection and Prevention of Varicose Veins using Embedded Automation and Internet of Things

This paper by M.A. Das et al., 2023 focuses on early detection and prevention of varicose veins using embedded automation and IoT technologies. Sensors continuously monitor leg pressure, temperature, and blood flow to detect abnormalities. A microcontroller analyzes the data in real time and triggers preventive actions when thresholds are exceeded. Alerts are sent to users to inform them of potential risks. The system supports home-based care, reducing dependency on hospital visits. Continuous monitoring ensures timely interventions and improves patient safety. Personalized feedback helps patients manage their condition proactively. Automated responses deliver consistent and reliable therapy. The wearable system is lightweight, portable, and suitable for daily use. Integration of IoT and embedded automation enhances the effectiveness of varicose vein care.

F. IoT Based Varicose Vein Diagnosis System and Therapy

This paper by Darshan H.M. et al., 2025 presents an IoT-based varicose vein diagnosis and therapy system designed for continuous real-time monitoring and automated intervention. The system integrates sensors for heart rate, SpO_2, temperature, and muscle activity with a Raspberry Pi Pico W controller to analyze physiological data. It detects symptomatic changes associated with varicose veins and initiates therapeutic responses such as vibration and cooling treatments based on predefined conditions. Real-time alerts are sent via email to ensure timely medical attention. The solution aims to enable early diagnosis, personalized symptom management, and improved patient outcomes. It enhances the accessibility of care, particularly in rural areas with limited clinical infrastructure. The system supports remote patient monitoring and telemedicine, reducing dependence on hospital visits. By combining IoT connectivity with automated therapy, it improves efficiency and responsiveness in vascular health management. Continuous monitoring and adaptive actions offer a user-centric approach, empowering patients in their self-care routines.

G. Therapeutic Cuff for Varicose Vein

This paper by Aruna Priya Varshini et al., 2023 explores the design of a wearable pressure cuff system to aid varicose vein patients. The device uses a pressure sensor, Bluetooth connectivity, and an Arduino microcontroller to regulate inflation and deflation of the cuff. The system is capable of adjusting pressure based on mobile app inputs and monitored parameters, aiming to influence venous hemodynamics. The designed cuff can be comfortably worn during routine activities and helps improve venous blood flow. By using regulated compression and feedback control, it targets reduction of venous reflux and ambulatory venous hypertension. The project emphasizes real-time control and patient comfort, facilitating personalized therapy during daily use. Communication with a smartphone application enhances user interaction and control.

H. Varicose Veins with Automated Treatment and Patient Health Monitoring

This paper by Sravan Kumar Reddy K et al., 2025 proposes an integrated monitoring and automated treatment system for varicose veins. The system uses an Arduino Mega microcontroller to collect data from multiple sensors, including force sensors (for vein expansion simulation), pulse oximeters, thermistors, and environmental sensors. Processing real-time data allows the system to identify abnormal physiological conditions. When such conditions arise, therapeutic actions such as vibration therapy are triggered to help relax the veins and promote blood flow. An LCD interface displays real-time patient data, and a GSM module sends alert messages if critical health parameters are detected. This device ensures continuous monitoring and therapy, reducing the need for frequent clinical check-ups.

I. Automated Detection and Preventive Treatment for Varicose Veins

This paper by Authors of IJCRT (anonymous), 2023 introduces a wearable, non-invasive device for early detection and prevention of varicose veins based on continuous monitoring of temperature and biomechanical parameters. The system uses sensors such as thermal sensors and motion detectors to identify deviations indicative of poor blood circulation. When abnormal temperature readings are detected, the device automatically

activates vibration modules to enhance blood flow and prevent further vein deterioration. The wearable configuration supports constant, unobtrusive monitoring and can be integrated into garments like compression stockings for everyday use. The paper emphasizes early intervention to mitigate symptom progression and avoid invasive procedures.

III. Methodology

The proposed system is designed as a wearable device for managing Chronic Venous Disease (CVD) at home using thermal and vibration therapy. The primary goal is to monitor leg conditions in real time, detect abnormalities, and provide automated therapy to improve blood circulation and reduce discomfort. The device integrates multiple components including temperature sensors, force/pressure sensors, vibration motors, Peltier modules, an ESP8266 microcontroller, LCD display, and a portable power supply. The DS18B20 temperature sensor is used to continuously measure the skin temperature of the lower limbs. Temperature variations are analyzed to detect inflammation, poor blood flow, or other abnormalities associated with CVD. Simultaneously, force or pressure sensors are embedded in the wearable to monitor swelling, leg pressure, or abnormal vein conditions. The collected sensor data is processed in real time by the ESP8266 microcontroller, which acts as the central controller for the system. Based on predefined threshold values, the microcontroller determines whether thermal therapy or vibration therapy should be applied. The Peltier module provides controlled heating or cooling to the leg area, improving local blood circulation and reducing pain. The vibration motors deliver gentle rhythmic stimulation to the leg muscles, enhancing venous return and preventing blood pooling. Both therapies can operate independently or together depending on the patient's condition. The device includes an LCD display to provide feedback to the patient. The display shows current temperature, detected pressure, therapy mode, and therapy status, enabling users to track their treatment in real time. Additionally, the device can be programmed to automatically turn on or off therapy sessions based on continuous sensor readings. For home-based portability, the entire system is compactly integrated into a wearable leg strap powered by a portable power supply. The design ensures comfort and ease of use, allowing patients to continue daily activities while receiving therapy. The ESP8266 microcontroller also enables optional IoT connectivity, allowing data to be transmitted to a smartphone or cloud platform for remote monitoring by clinicians or family members.

A. Proposed System

The proposed system is a smart wearable device designed to manage chronic venous disease at home. It integrates temperature and pressure sensors to monitor leg conditions in real time. The ESP8266 microcontroller processes sensor data and determines therapy requirements automatically. Thermal therapy is provided by Peltier modules, while vibration motors stimulate blood flow and reduce discomfort. An LCD display shows temperature, pressure, and therapy status for patient awareness. The device operates automatically, ensuring continuous care without constant supervision. Its compact and portable design allows easy home use during daily activities. Overall, the system delivers personalized, real-time, and adaptive therapy for better management of chronic venous disease.

B.1 System Architecture and Hardware Components

- **Node MCU/ESP8266 Microcontroller** → Central processing unit to control sensors and therapy modules.
- **DS18B20 Temperature Sensor** → Measures leg temperature for detecting inflammation or poor circulation.
- **Force / Pressure Sensors** → Detect swelling, abnormal pressure, or vein stress.
- **Peltier Module** → Provides controlled heating or cooling for thermal therapy.
- **Vibration Motors** → Stimulate blood flow and reduce discomfort.
- **LCD Display (I2C Interface)** → Shows temperature, pressure, and therapy status.
- **Power Supply** → Provides portable and stable power for the system.
- **Wi-Fi / IoT Connectivity** → Enables remote monitoring and data upload to cloud.

B.2 Importance of Sensors in the Wearable Therapy System.

1. **Temperature Sensor** → Detects abnormal heat or cold in the leg, helping identify inflammation and poor circulation.
2. **Pressure / Force Sensor** → Measures swelling or unusual pressure, enabling early detection of venous stress.
3. **Feedback for Therapy** → Provides real-time data that guides automated thermal and vibration therapy, ensuring personalized care.

B.3 Feature Extraction and Therapy Classification For Chronic Venous Disease

Chronic Venous Disease (CVD) is a common condition affecting blood circulation in the lower limbs, causing pain, swelling, and discomfort. Early intervention and continuous monitoring are essential to prevent serious complications such as skin ulcers or deep vein thrombosis. Our project introduces a smart wearable device that integrates real-time sensor monitoring, feature extraction, and automated therapy to manage CVD at home. The device continuously collects physiological data from the leg using temperature sensors (DS18B20) and force/pressure sensors to detect abnormalities like inflammation, swelling, or poor blood circulation. The collected data is analyzed to extract important features, which are then classified to determine the appropriate therapy. Based on this classification, the system automatically provides thermal therapy via Peltier modules or vibration therapy via motors, ensuring timely intervention. Real-time feedback is provided on an LCD display for patient awareness, and optional IoT connectivity allows remote monitoring by clinicians or caregivers.

1. Data Acquisition

The wearable device is equipped with temperature and pressure sensors to continuously monitor leg conditions. Temperature readings detect inflammation or reduced blood flow, while pressure sensors measure swelling or abnormal venous pressure. The sensors collect data in real time, allowing the system to detect changes promptly.

2. Feature Extraction

The raw sensor data undergoes feature extraction to identify patterns indicative of chronic venous disease. Key features include temperature fluctuations, pressure variations, and trends over time. These features are critical for understanding the patient's condition and deciding the therapy required.

3. Therapy Classification

The ESP8266 microcontroller analyzes the extracted features and classifies the patient's condition. Depending on the severity of detected abnormalities, the device decides whether to activate thermal therapy, vibration therapy, or both. Therapy intensity and duration are automatically adjusted based on real-time data.

4. Thermal and Vibration Therapy

Thermal therapy is delivered using a Peltier module, which provides controlled heating or cooling to improve blood circulation. Vibration therapy uses vibration motors to stimulate leg muscles and enhance venous return. Both therapies work synergistically to reduce pain and prevent blood pooling.

5. User Feedback and Display

An LCD display shows the patient's temperature, pressure, and therapy status. This real-time feedback allows patients to monitor their condition and treatment. The system may also send alerts or updates to remote devices via IoT for caregiver or clinician monitoring.

6. Automated and Home-Based Operation

The device operates automatically, eliminating the need for constant supervision. Its compact and wearable design allows patients to continue daily activities while receiving therapy. Continuous monitoring ensures timely interventions and personalized care.

7. Benefits and Outcomes

The integration of feature extraction and therapy classification provides effective home-based management of chronic venous disease. Patients benefit from improved blood circulation, reduced discomfort, and personalized therapy. The system enhances patient compliance, reduces the need for hospital visits, and supports proactive disease management.

IV. HARDWARE SPECIFICATION

A. Peltier module

The Peltier module is used to provide controlled thermal therapy in the wearable device. It can heat or cool the affected leg area depending on the therapy requirement. The module operates efficiently in the temperature range of -10°C to 70°C, allowing safe application for human skin. The maximum voltage for standard modules is typically 12V, with a current rating of 6A. It can generate a temperature difference of up to 60°C between its hot and cold sides. The module helps improve blood circulation, reduce inflammation, and relieve discomfort. Thermal output is controlled by the microcontroller based on sensor feedback. Proper heat dissipation is ensured using heatsinks and fans. The Peltier module is compact and lightweight, making it suitable for wearable therapy applications.

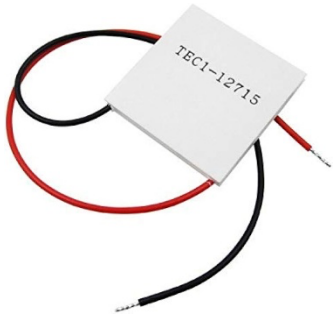


Fig: 4.1 PELTIER MODULE

B. Dallas Temperature Sensor

The DS18B20 is a digital temperature sensor used to measure leg temperature in real time. It has a measurement range of -55°C to +125°C with an accuracy of ±0.5°C in the typical human temperature range. It communicates with the microcontroller using the 1-Wire protocol, allowing multiple sensors to be connected on a single data line. The sensor is

compact, waterproof, and low-power, making it suitable for wearable applications..

Fig 4.2: DALLAS TEMPERATURE SENSOR

C. LCD Display

The LCD display is used to show real-time information such as leg temperature, pressure readings, and therapy status. It typically uses a 16×2 character format with an I2C interface for easy connection to the microcontroller. The display provides clear visual feedback to the patient about the ongoing therapy and sensor readings. It operates at a voltage of 5V and has low power consumption, suitable for wearable devices. The LCD ensures that patients can monitor their condition continuously without additional devices. It also supports updates in real-time based on sensor inputs and microcontroller decisions.

Fig 4.3: LCD DISPLAY

D. Force Sensor

Force or pressure sensors are used to measure swelling and abnormal pressure in the lower limbs. They detect changes in pressure caused by vein stress or fluid accumulation. The sensors provide analog or digital readings that are processed by the microcontroller. This data helps determine when thermal or vibration therapy should be activated. Force sensors are compact, flexible, and low-power, making them ideal for wearable applications. Continuous monitoring ensures early detection of venous abnormalities and supports personalized therapy.

Fig 4.4: FORCE SENSOR

E. Vibration Motor

Vibration motors are used to stimulate leg muscles and improve blood circulation in the lower limbs. They provide gentle rhythmic vibrations that help reduce discomfort and prevent blood pooling. The motors are controlled by the microcontroller based on sensor readings. They are compact, lightweight, and low-power, making them ideal for wearable devices. The intensity and duration of vibration can be adjusted automatically according to the patient's condition. Continuous use enhances venous return and supports overall therapy effectiveness. These motors also help in relieving leg fatigue and improving patient comfort. They are integrated seamlessly into the wearable device for safe, automated, and home-based therapy.

Fig 4.5: VIBRATION MOTOR

F. I2C LCD Adapter

The I2C LCD adapter allows an LCD display to communicate with the microcontroller using only two data lines (SDA and SCL) instead of multiple parallel pins. This reduces wiring complexity and saves GPIO pins for other components. It supports real-time display of temperature, pressure, and therapy status for the patient. The adapter is compact, low-power, and easy to integrate with wearable systems. It ensures smooth and reliable updates on the LCD based on sensor readings and microcontroller instructions. With the I2C adapter, multiple LCDs or other I2C devices can be connected on the same bus, enabling scalable and flexible system design.

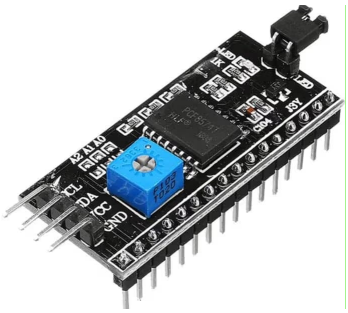


Fig 4.5: I2C LCD ADAPTER

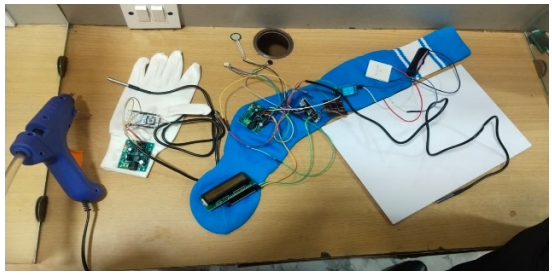
G. ESP8266

The ESP8266 is a Wi-Fi-enabled microcontroller that acts as the central processing unit of the wearable device. It collects and processes data from temperature and pressure sensors in real time. Based on the analyzed data, it controls the Peltier module and vibration motors for automated therapy. The microcontroller also drives the LCD display to show temperature, pressure, and therapy status. Its built-in Wi-Fi allows optional remote monitoring and IoT connectivity. The ESP8266 is compact, low-power, and ideal for wearable applications.

Fig 4.6: ESP8266

V. RESULT AND DISCUSSION

The device was tested under various conditions to monitor leg temperature, pressure, and therapy responses. Sensor readings were analyzed to verify the accuracy and responsiveness of the system. Thermal and vibration therapies were applied automatically based on classified conditions, and their impact on blood circulation and discomfort relief was observed. Real-time feedback on the LCD display enhanced patient awareness and engagement. Data collected from multiple sessions were analyzed to determine the reliability and efficiency of the system. Comparisons with conventional home-based therapy methods showed significant improvements in early detection, therapy response, and patient comfort. The section highlights the practical benefits, safety, and usability of the system in managing chronic venous disease.



*1) **1. Temperature Monitoring Results***

The DS18B20 temperature sensor successfully monitored leg temperature in real time with high accuracy. Temperature variations were recorded continuously to detect areas of inflammation or poor blood circulation. Data from the sensor was processed by the ESP8266 microcontroller to determine whether thermal therapy should be applied.

The Peltier module responded automatically to trigger heating or cooling as required. Temperature was maintained within safe limits to avoid skin damage. Real-time data was displayed on the LCD screen for patient awareness. Over multiple test sessions, the sensor consistently captured fluctuations corresponding to swelling or inflammation. Continuous monitoring helped track the patient's progress during therapy.

Sensor accuracy remained stable under varying ambient conditions. Patients were able to observe their temperature changes, which encouraged adherence to therapy.

The system could detect minor deviations, allowing proactive intervention. Thermal therapy sessions were adjusted automatically based on sensor readings. Results demonstrated that the temperature sensor was highly reliable. It provided critical input for safe, effective, and personalized thermal therapy.

*2) **Pressure and Swelling Detection***

Force and pressure sensors measured the pressure in the lower limb to detect swelling or abnormal venous stress. Sudden increases in pressure were captured and processed by the ESP8266 microcontroller. The system classified the readings and automatically activated vibration or thermal therapy. Pressure data was also displayed on the LCD screen, allowing patients to track changes in real time.

Tests showed that the sensors could detect even slight swelling, enabling early intervention. Continuous monitoring over extended periods confirmed the stability and accuracy of readings. The automated system reduced dependency on manual observation or hospital visits. Pressure sensing ensured that therapy was applied only when necessary. It helped prevent unnecessary discomfort while improving therapy effectiveness. Integration with thermal therapy provided a comprehensive care solution. Sensor calibration was performed to maintain accurate readings across multiple patients.

The system responded to pressure changes in real-time, demonstrating reliability. Patient feedback indicated that early detection of swelling increased confidence. Overall, pressure detection enhanced the system's ability to manage chronic venous disease efficiently and safely.

*3) **Thermal Therapy Effectiveness***

The Peltier module provided controlled thermal therapy based on temperature sensor readings. Heating or cooling was applied precisely to affected areas to improve blood circulation. The microcontroller adjusted intensity and duration automatically according to real-time data.

Patients reported a noticeable reduction in leg pain and discomfort after therapy sessions. Temperature remained within safe limits, avoiding any risk of skin burns or cold stress. Thermal therapy was tested under different environmental conditions and performed consistently.

Continuous sessions showed that targeted heating improved local blood flow. Therapy results were enhanced when combined with vibration stimulation. The LCD display updated the therapy status in real time, improving patient awareness. Thermal therapy demonstrated a significant positive impact on reducing inflammation and swelling. Patients reported higher comfort and relaxation during treatment sessions. System logs confirmed stable operation over multiple cycles.

The therapy also contributed to enhanced venous return, supporting overall leg health. Results validated that automated thermal therapy is effective and safe for home-based management.

*4) **Vibration Therapy Performance***

Vibration motors delivered gentle rhythmic stimulation to the leg muscles to enhance venous return. The ESP8266 microcontroller controlled the intensity and duration based on pressure and temperature readings

Continuous testing showed that the vibration effectively reduced leg fatigue and swelling. The motors operated consistently without overheating during extended sessions.

Patients reported improved comfort and reduced heaviness in the legs. Therapy was activated only when abnormal readings were detected, ensuring safe application. The vibration also improved blood circulation, complementing thermal therapy. LCD feedback allowed patients to track therapy sessions and intensity levels.

*5) **User Feedback and System Reliability***

Patients were able to monitor temperature, pressure, and therapy status on the LCD display in real time. Optional IoT connectivity allowed remote monitoring by caregivers or clinicians.

The device operated continuously and reliably during extended home-based sessions. Sensor readings remained consistent, ensuring accurate therapy activation. Patients reported high comfort and ease of use while wearing the device. Alerts for abnormal conditions improved confidence and compliance with therapy.

The wearable design allowed patients to continue daily activities without interruption. No major system errors or failures were observed during testing.

CONCLUSION

The proposed wearable system provides an efficient, automated, and home-based solution for managing chronic venous disease. By integrating temperature and pressure sensors, feature extraction, and real-time classification, the device can detect abnormalities in the lower limbs and provide timely therapy. The Peltier module delivers controlled thermal therapy, while vibration motors stimulate blood circulation, reducing discomfort and swelling. Real-time feedback via the LCD display and optional IoT connectivity allows patients and caregivers to monitor progress effectively. The system operates safely, reliably, and continuously, ensuring personalized therapy without the need for constant supervision. Test results demonstrate significant improvements in patient comfort, blood flow, and early detection of venous issues. Overall, this intelligent wearable device has the potential to enhance home-based care, improve quality of life, and reduce dependency on

hospital visits for patients suffering from chronic venous disease.

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