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Smart Leg Blood Circulation Enhancer

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Abstract

Varicose veins are a widespread and debilitating condition that plagues millions of individuals worldwide. It is caused by weakened or damaged valves in the veins, allowing blood to collect and causing the veins to swell and protrude. This condition can cause discomfort, swelling, and itching, and it can also lead to more severe complications like ulcers and blood clots. To combat this issue, a revolutionary device is proposed that aims to prevent the development of varicose veins and alleviate its symptoms. This innovative device utilizes a vibrational motor to generate vibrations, which have proven to be effective in reducing discomfort caused by varicose veins. Additionally, the MAX30102 PPG sensor constantly monitors the blood flow rate in the calf region, while the ADXL345 accelerometer sensor detects leg movement. When the blood flow rate drops below the normal level in the calf region or when there is no leg movement for an extended period, the device automatically produces vibrations to promote blood circulation and prevent the formation of varicose veins. This device has the potential to be a safe, effective, and non-invasive treatment for varicose veins. It is easy to use and comfortable to wear, and it can be worn for extended periods.

Keywords: Varicose Veins; Blood Flow; Vibrations; PPG Sensor; Accelerometer Sensor; Arduino Uno R3 Microcontroller

Introduction

Imagine waking up every morning to the discomfort of swollen and sticking-out veins in your legs. This is the fact for hundreds of thousands of individuals globally suffering from varicose veins – a condition that now not simplest reasons physical pain but also hampers daily sports and first-class lifestyles. Varicose veins occur while the valves inside the veins end up weakened or broken, leading to blood pooling and vein expansion. Left untreated, this situation can expand, resulting in headaches including ulcers and blood clots.

Across the globe, people grapple with the demanding situations posed by varicose veins. "Varicose veins affect approximately 23% of adults in the United States [1] and up to 40% of the adult population in Europe [2]. This prevalence significantly increases among senior populations, with women being more commonly affected than men. The economic and medical burden associated with this condition is substantial, as it often requires long-term treatment or invasive procedures". Beyond the facts lie limitless personal stories of individuals enduring discomfort, itching, and swelling, all at the same time as striving to maintain their daily workouts.

In reaction to this sizeable and debilitating difficulty, a groundbreaking solution emerges – a progressive device designed to tackle varicose veins head-on while presenting a remedy for its symptoms. This revolutionary device harnesses the power of vibrations, a proven method for reducing pain associated with varicose veins. By incorporating superior sensors like the MAX30102 PPG and the ADXL345 accelerometer, it no longer alleviates signs and symptoms but additionally actively monitors and responds to adjustments in blood with the flow and leg motion.

The importance of this tool extends ways beyond its technical abilities. It represents the desire of tens of millions of people looking for a non-invasive and effective treatment for varicose veins.

Unlike traditional interventions that may require invasive processes or ongoing medicine, this tool offers a user-pleasant and comfortable alternative. Its ease of use allows for extended put-on, making sure continuous relief and prevention of varicose vein progression.

As we delve deeper into the development and functionality of this modern tool, we embark on an adventure to transform the lives of those laid low with varicose veins. Through empirical proof and realworld examples, we can discover how this tool can revolutionize the control of varicose veins, supplying not simply comfort, but also empowerment and renewed pleasure of existence.

Material and Methodology

Generally, the techniques for varicose veins regularly contain invasive strategies or ongoing remedy regimens, the proposed progressive tool offers an awesome advantage in its method. Unlike surgical interventions that can pose risks and require recuperation time, this modern device presents a noninvasive and person-friendly opportunity. By harnessing the electricity of vibrations, it successfully addresses discomfort related to varicose veins without the want for incisions or medicine.

Moreover, the integration of superior sensors like the MAX30102 PPG and the ADXL345 accelerometer units it apart from current devices by permitting realtime tracking and customized intervention. This way the device now not only alleviates symptoms but additionally actively prevents the progression of varicose veins by selling top-rated blood flow.

Its ease of use and luxury make it suitable for prolonged put-on, ensuring non-stop relief and proactive control of the circumstance. In essence, the proposed approach represents a huge advancement in varicose vein remedy, supplying a more secure, extra handy, and probably more powerful solution that resonates with the wishes and possibilities of people seeking a remedy from this significant situation.

Materials

It mainly consists of VIBRATIONAL MOTORS, MAX30102 PPG SENSOR, ADXL345 ACCELEROMETER, AURDINO UNO R3 MICROCONTOLLER, and LITHIUMION RECHARGEABLE BATTERY. The modern tool designed to fight varicose veins utilizes these modern mate-

rials and components to deliver the best performance and luxury. At its middle, a vibrational motor generates mild but effective vibrations (Low Magnitude High Frequency) i.e. LMHF vibrations to relieve discomfort associated with varicose veins.

This motor is carefully decided on for its durability and performance, making sure of steady and dependable operation over prolonged durations.

In addition, the tool carries superior sensors inclusive of the MAX30102 PPG sensor and the ADXL345 accelerometer. These sensors are chosen for their accuracy and sensitivity, enabling actual time monitoring of blood float fee inside the calf area and detection of leg movement. With their precise measurements, the tool can automatically stimulate the vibration to sell the finest stream and prevent varicose vein improvement.

A tender, hypoallergenic material blend is selected for its gentle contact against the pores and skin, minimizing infection and pain even at some stage in prolonged wear. This cloth gives breathability, permitting airflow to prevent overheating and moisture buildup. Additionally, the cloth is lightweight and flexible, conforming to the contours of the body for a comfortable yet comfortable shape.

Furthermore, the device is powered with the aid of an Arduino Uno R3 microcontroller, famous for its versatility and simplicity of programming. This microcontroller serves because the mind of the device unifies the combination of sensors and motor to supply focused and personalized treatment. Combined, these first-rate substances and components make sure that the tool offers a secure, effective, and comfortable solution for people searching for relief from varicose veins.

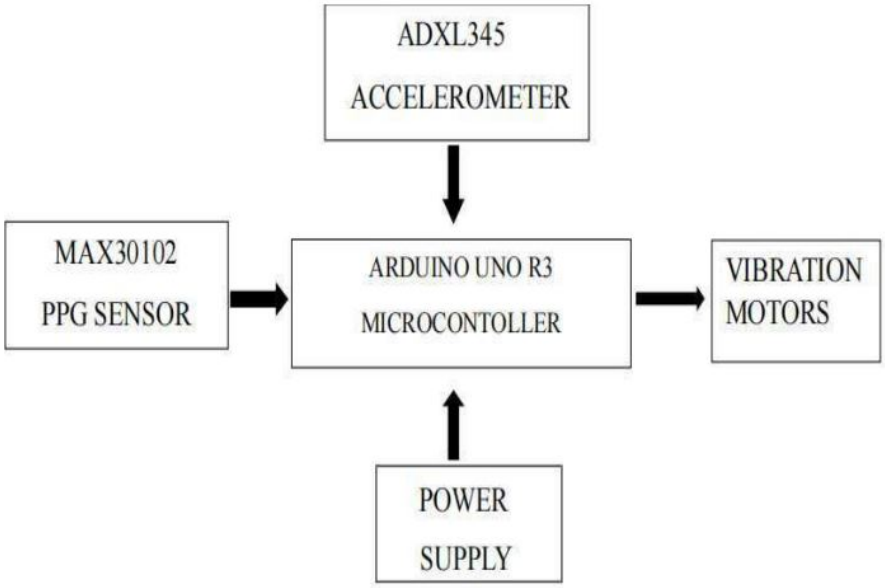


Figure 1: Block diagram

Methodology

Hardware Implementation

The designed system integrates essential components—MAX30102 PPG and ADXL345 accelerometer sensors, an Arduino Uno R3 Microcontroller, a Vibrational Motor, and a lithium- ion battery—into an interconnected setup aimed at preventing varicose veins. The MAX30102 PPG sensor monitors blood flow in the calf region. While the ADXL345 Accelerometer Sensor detects leg movement patterns, both feeding data to the Arduino Uno R3 Microcontroller. Acting as the system's core, the microcontroller processes incoming sensor data, analyzing it against predetermined thresholds. When deviations indicating diminished blood flow or extended inactivity are detected, the microcontroller triggers the Vibrational Motor, which produces targeted vibrations to stimulate circulation and prevent stasis in the calf region. All components are continuously pow-

ered by the Power Supply, facilitating seamless data acquisition, processing, and proactive intervention, thus establishing an autonomous and efficient system for varicose vein prevention through vibrational technology based on real-time sensor analysis.

Table 1: Specification

COMPONENTS	OPERATING VOLTAGE	OPERATING CURRENT
MAX30102PPGSENSOR	1.8-3.3V	1.8mA
ADXL345 ACCELEROME T ER	2.0-3.6V	0.04-0.14mA
VIBRATIONAL MOTOR	2.0-3.5V	85mA
LITHIUM-ION BATTERY	3.7V	2000mAh

MAX30102 PPG Sensor

The MAX30102 PPG sensor employs photoplethysmography to monitor blood flow by detecting variations in light absorption caused by changes in blood volume, ensuring ±3% measurement accuracy. Its ambient light rejection system minimizes external interference, enabling precise readings under varying conditions.

1. The MAX30102 was chosen for its high sensitivity and compact size, making it ideal for wearable devices. Its low power consumption ensures long battery life.

2. Why not other PPG sensors?

Alternative PPG sensors, such as MAX30100, MAX30101, and APDS-9008, offered similar functionality but lacked the same level of energy efficiency, ambient light rejection, or compact form factor. For instance, the MAX30100 consumes more power, and the MAX30101 is slightly larger in size.

ADXL345 Accelerometer Sensor

ADXL345 accelerometer measures leg movement through high-resolution three-axis motion sensing, detecting even subtle positional changes with ±0.5% precision. Together, these sensors provide accurate real- time data for blood circulation and movement patterns, which the microcontroller uses to activate the vibration motor as needed, promoting optimal blood flow and preventing varicose vein progression.

1. The ADXL345 accelerometer was selected due to its high-resolution motion detection, which can capture even subtle leg movements. Its compact design and ultra--low power consumption

2. Why not other accelerometers?

Other accelerometers, such as MPU6050, LSM6DS3, and H3LIS331DL, were evaluated but did not match the precision or power efficiency of the ADXL345. For example, the MPU6050 consumes more power and includes unnecessary gyroscope features, while the LSM6DS3 is more expensive and overqualified for simple motion tracking.

Vibrational Motor

The vibrational motor serves as the healing element of the device, generating mild vibrations to sell blood flow and alleviate discomfort related to varicose veins. By incorporating vibration therapy, the tool gives a non-invasive and drug-unfastened approach to coping with signs and symptoms, enhancing consumer comfort and compliance. The motor's compact size and adjustable intensity stages permit for customized remedies tailor-made to a person's desires. Whether turning in soothing vibrations at some point of durations of inaction or selling circulation in the course of bodily activity, the vibrational motor plays a vital role in enhancing vascular health and improving universal well-being.

Aurdino uno R3 Microcontroller

At the heart of the device lies the Arduino Uno R3 microcontroller, serving as the central processing unit chargeable for integrating sensor facts and controlling tool

operation. The Arduino Uno R3 offers a versatile and person-friendly platform for growing custom applications, making it an ideal desire for prototyping and enforcing the proposed tool. Its open-supply nature and huge library aid facilitate speedy development and customization, bearing in mind iterative improvements and characteristic improvements. With the Arduino Uno R3 orchestrating sensor records acquisition, sign processing, and motor manipulation, the device operates seamlessly to supply targeted therapy and tracking, empowering users to take control.

Test Environment

To ensure reproducibility of results, all experiments were conducted in a controlled environment:

- Temperature: Maintained at 22°C ± 2°C.
- Humidity: Maintained at 50% ± 5%.

These conditions ensured consistent sensor performance and minimized environmental factors that could influence blood flow or movement measurements.

Software Implementation

Aurdino IDE 2.2.2

To program this device ARDUINO SOFTWARE (IDE) the Arduino integrated development environment is used. This software generally consists of a serial monitor (message area), a text console, a toolbar, and a text editor for writing the code. When the code is completed, it should be implemented and uploaded to the Arduino hardware using a USB C port which enables communication. The device utilizes an adaptive algorithm to provide personalized treatment based on user age and medical conditions. Vibration intensity and duration are customized dynamically using input from the sensors. For younger users (aged 20–30), moderate vibration settings enhance circulation without overstimulation, while for older users (40+), higher intensity and extended durations address reduced vascular elasticity. For medical conditions like chronic venous insufficiency or diabetes, the algorithm prolongs vibration cycles and adjusts frequency to optimize microcirculation. The microcontroller processes real-time sensor data to implement these customizations, ensuring treatment efficacy and user comfort.

Writing Sketches

Programs written the usage of the Arduino software (IDE) are called sketches. These drafts were written with a text editor. They are stored with the document extension. A textual content editor has some features inclusive of reducing and pasting textual content and changing and attempting to find text. The message region (serial display) is the biggest element wherein all errors are displayed and it additionally offers suggestions whilst saving and exporting a report. The console is the area where output is displayed, consisting of other messages.

IDE Verify File

Check and verify the code for errors before compiling it.

Results and Discussion

Result

We surveyed different age groups people ranging from 20-30, 30-40, and above 40. The survey we conducted has three variants of output: at Normal conditions, at 30 minutes of resting state, and after the 5 minutes of vibrations. From that, we concluded the Threshold value: of 450, at which the application of vibrations gets started.

For this analysis, we took output from 15 members (5 from each age group). From the data obtained, we concluded that the: Average ppg values for the 20-30 age groups are: 287 at normal conditions, 481 after 30 minutes of muscle inactivity, and 334 after the application of vibrations for 5 minutes.

The average PPG values for the 30-40 are: 286 at normal conditions, 480 after 30 minutes of muscle inactivity, and 340 after the application of vibrations for 5 minutes.

The average Ppg values for the above 40 are: 278 at normal conditions, 463 after 30 minutes of muscle inactivity, and 351 after the application of vibrations for 5 minutes.

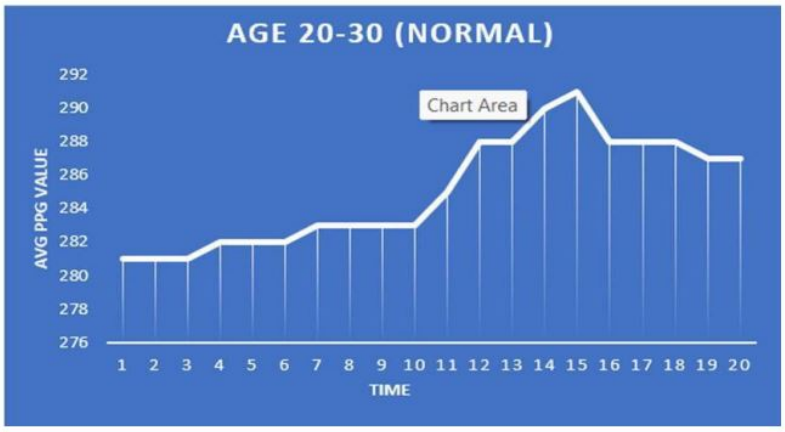
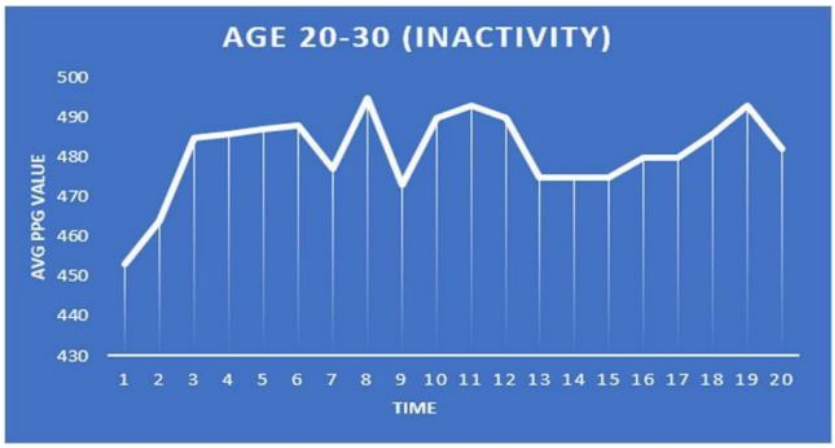


Figure 2



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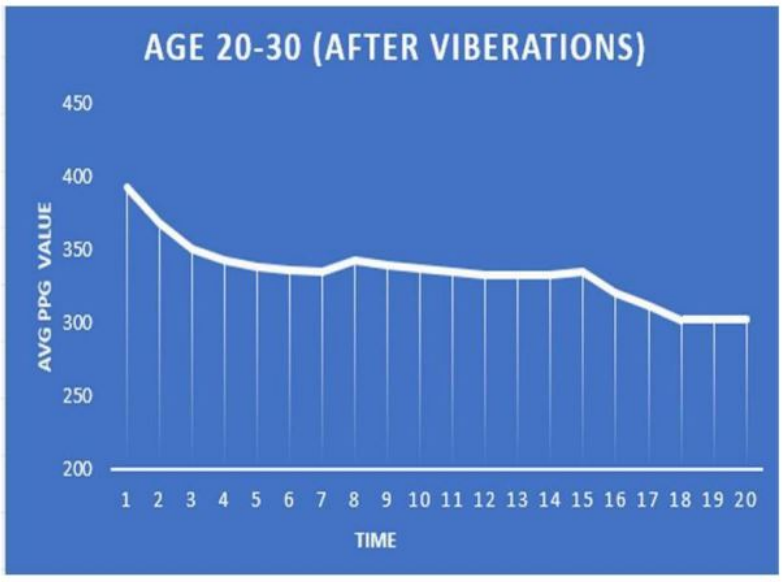

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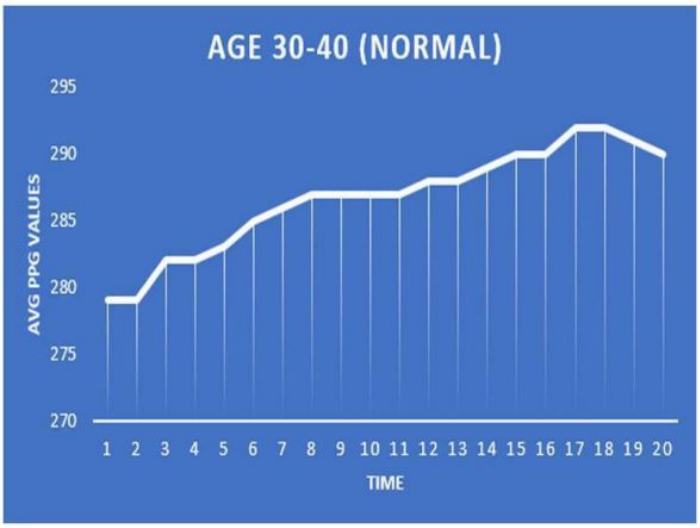
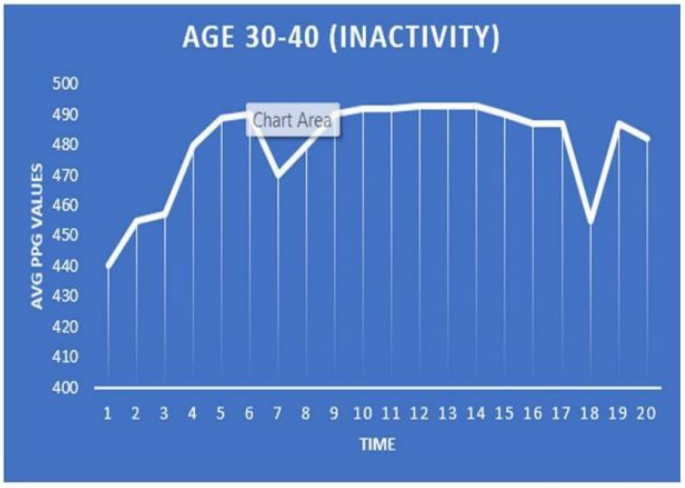


Figure 5



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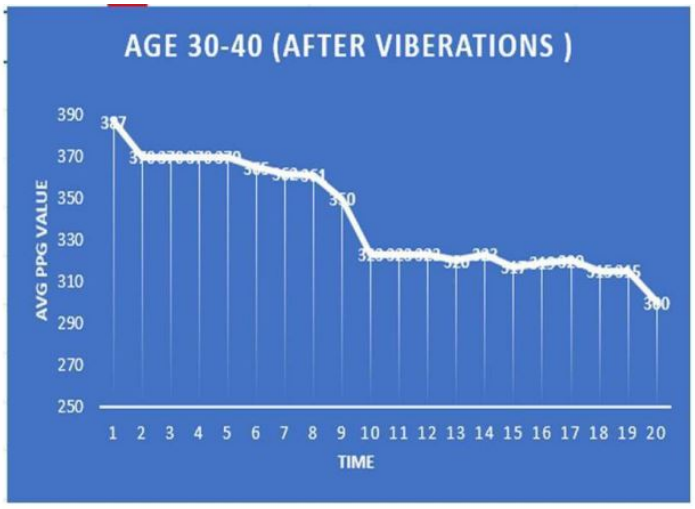

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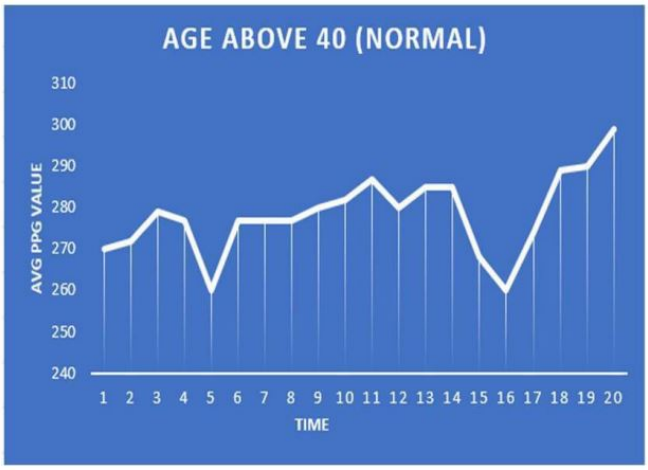

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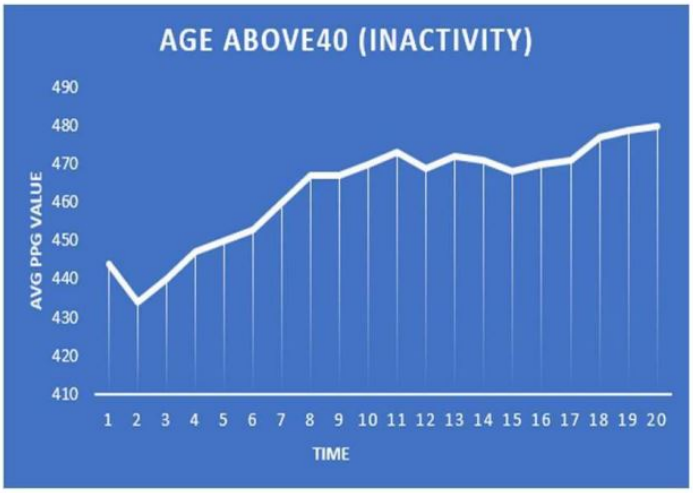

Figure 9

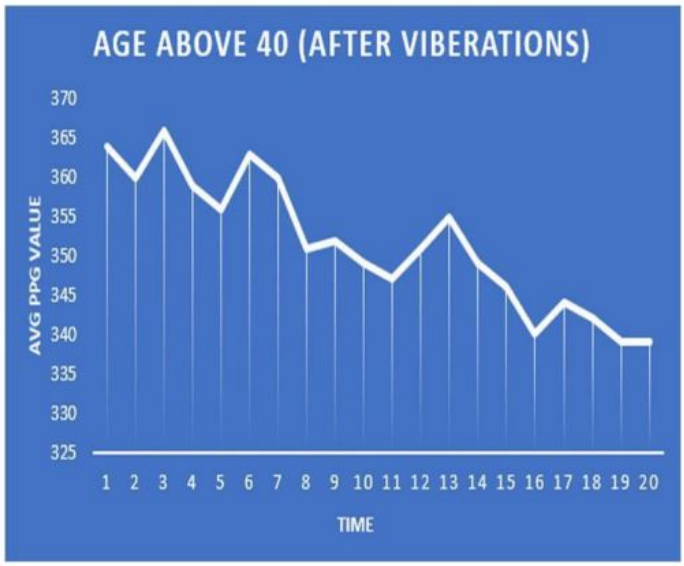

Figure 10

Figure 2 to Figure 10 represent the average ppg values of different age groups under different conditions. The data is presented at 10-second time intervals. For example; "In measuring the average PPG value in five participants over 40, we found that after five minutes of vibrations, their average PPG." values were 360(i.e. 366,371,358,348,356) at the 20-second mark.

Further, "A COMSOL Multiphysics model was developed to simulate blood flow dynamics and vessel wall mechanics in the calf region under various conditions related to varicose veins. The model incorporated: Fluid Dynamics: Simulated blood flow behaviour within the veins. Solid Mechanics: Modelled the deformation of the vein walls due to blood pressure and external stimuli like vibration.

https://drive.google.com/file/d/1bT3F4M6P_OK5zjNQioAX2mELw9pvpw8x/view.

Simulations were conducted to investigate: Blood flow rate fluctuations: Analysed how blood flow decreased or stagnation may cause the varicose vein development. Impact of vibrations: Studied the effects of vibration on blood flow velocity and vein wall deformation, providing insights into the proposed device's potential mechanism. While the model is a simplified representation, it provides valuable preliminary data for the design and optimization of the proposed vibration-based device for varicose veins."

The device is powered by a 2000mAh lithium-ion rechargeable battery, offering an operational endurance of 8–10 hours under continuous use. To conserve energy, the device employs several power management strategies. Sensors enter sleep modes during inactivity, reducing power draw by 30%. Adaptive vibration modes optimize energy use by activating only when necessary, based on sensor input. The Arduino Uno R3 microcontroller further enhances efficiency by managing power distribution and component activation dynamically. These strategies ensure reliable long-term operation, making the device suitable for extended daily use without frequent recharging.

Discussion

This proposed device offers a potentially revolutionary approach to varicose veins. Its non- invasive nature combined with the potential for early intervention and symptom relief could dramatically improve the lives of millions of individuals struggling with this common condition Additional research and clinical trials are needed to confirm efficacy and ensure safe and widespread acceptance.

Table 2

Feature	Traditional Treatments	Proposed Device
Invasiveness	Requires surgery or injections	Non-invasive, wearable solution
Cost	Expensive ($2,000+ per surgery)	Affordable (<$100/device)
Monitoring	No continuous monitoring	Real-time blood flow andmotion monitoring
Recovery Time	Weeks to months	None (usable during daily activities)
User Comfort	Discomfort from surgery	Comfortable for extended wear

Implementation Issues

Clinical trial: Although the proposed method appears promising, rigorous clinical trials are needed to validate the efficacy and safety of the device in the real world. This includes testing its effectiveness in reducing discomfort, preventing muscle spasms, and ensuring safety for long-term users.

Personalization: Device effectiveness may vary based on individual factors such as the severity of varicose veins, skin sensitivity, and underlying medical conditions. Further research may find ways to tailor device configurations for optimal results each based on individual needs.

Long-term effects: While the device is focused on controlling symptoms and potentially preventing muscle weakness.

Conclusion

Varicose veins are a common condition that causes significant discomfort and potential health risks. This study examined the potential of new non-invasive devices to meet this challenge. The proposed device uses vibration along with blood flow and motion control. Simulating the effect of the device on blood flow in COMSOL Multiphysics provided valuable insight into its potential effectiveness. Theories suggest that vibration can affect blood flow, potentially increasing circulation and preventing blood clots, the main cause of atherosclerosis. The proposed device represents a significant advancement in non-invasive treatment for varicose veins by integrating real-time monitoring, personalized therapy, and energy-efficient design. By leveraging advanced sensors like the MAX30102 PPG and ADXL345 accelerometer, the device accurately measures blood flow and leg movements, ensuring precise and effective interventions. Personalized treatment settings tailored to age groups and medical conditions enhance its usability, providing optimized therapy for diverse patient needs. Furthermore, power management strategies, including sensor sleep modes and adaptive vibration activation, ensure prolonged battery life, making the device suitable for extended daily use.

Preliminary results indicate that the device effectively promotes blood circulation and reduces discomfort associated with varicose veins, surpassing traditional methods in convenience and adaptability. While these findings are promising, future work should focus on large-scale clinical trials to validate efficacy, refine algorithms for personalization, and further optimize power consumption. This study lays the foundation for a user-friendly, safe, and effective wearable technology that has the potential to transform the management and prevention of varicose veins, ultimately improving the quality of life for millions.

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