Design of Homeostatic Temperature Control System for Hypohidrosis Patients and its effect on EEG waveform

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Abstract : **Hypohidrosis is a sweating disorder that arises as a consequence of malfunctioning sweat glands due to which the human body is unable to lower its temperature. This condition can be a threat to human health as it causes severe health conditions like heat stroke. The proposed device is entirely dependent on the working principle of the thermoelectric cooler (TEC) and LM35 where LM35 helps in the detection of body temperature, as well as atmospheric temperature while the thermoelectric cooler, is used to demote the body temperature. Arduino programming is utilized to direct the working of the device to maintain the desired temperature of the body. Whenever the body temperature increases beyond normal (37°C) set through programming, the LM35 detects it and sends signals to the relay to become normally open so as to start the working of TEC. This will start to cool down the body from its cooling side attached to the skin and exhale out the excessive heat in the atmosphere from its heating side until the desired body temperature is attained. The EEG electrodes are also connected to detect the electrical activity of the subjects to analyze the effect of this device on the EEG waveform therefore the recording is taken without the device and then with the device in different conditions to interpret the effect of lowering down of temperature on the brain. This idea of investigating brain waves is significant to overcome any pessimistic effect on human body during the functioning of TEC. With the rising body temperature due to Hypohidrosis, the voltage of the thermoelectric cooler decreases which ultimately lowers the temperature of the body. This is a user-friendly device that aims to provide the desired comfort to patients with Hypohidrosis; they can enjoy their normal lifestyle, work, and roam out on a sunny day without having to worry about their disease. Moreover, this is an inexpensive device designed from a commercial point of view to meet the medical uses related with sweating disorders.**

***Keywords*—Hypohidrosis, Sweating, Body Temperature, Thermoelectric cooler, EEG**

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I. INTRODUCTION

Sweating is a crucial mechanism by which the human body lowered its temperature. However, there is a condition in which individuals face problems as an outcome of malfunctioning of their sweat glands, they do not sweat in a normal manner leading to a condition known as Hypohidrosis [1]. Hyperthermia i.e. the elevation of body temperature is the outcome of Hypohidrosis which can further lead to nervous breakdown [2]. Another intense complex sweating disorder where there is a complete loss of sweating from the body under a medical condition is termed Anhidrosis [3]. Moreover, Ectodermic dysplasia is a condition in which there is an abnormality of the ectodermic layer which fundamentally affects the different organs including sweat glands [4]. Contrarily, Hypohidrosis involves an abnormality of sweating as a result of thermal changes that are faced by the patient. Hence, both conditions lead to the disturbance of the human mechanism of sweating. Some other causes of hyperthermia include malfunctioning of certain organs, improper anatomical function, and problematic biochemical mechanisms related to the secretion of sweat [5]. The condition of hyperthermia can be localized to a particular area of the body as well as the entire body. Hypohidrosis is also known to be spotted in different parts of the body. When a person is unable to sweat normally, the human body gets heated up. This is dangerous because it can lead to life-threatening conditions like heat stroke [6]. Some common symptoms of Hypohidrosis include palpitations, nausea, and hyperpyrexia followed by a state of dizziness [7],[8]. A few individuals develop Hypohidrosis as a secondary disease when diseases like psoriasis [9] and Rose syndrome [10] are already present as the primary disease. Damage to the skin [11] and usage of some drugs are also responsible for the occurrence of this condition [12]. It becomes extremely difficult for the patients of Hypohidrosis to survive under hot weather and they may also bear severe glandular and hormonal imbalances leading to various disorders. Such patients tend to stay at home because they cannot tolerate high temperatures. Therefore, they cannot step out on hot sunny days so, in order to ease their life and motivate them, a device is designed. The following device is based on the Peltier effect induced by a thermoelectric cooler [13] thus declining the body temperature. Furthermore, the electrical activity of the brain was inscribed by EEG waveform which is the aggregation of activities of thousands of neurons in the form of alpha waves, beta waves, delta waves and theta waves. For this purpose, Biopac Science Lab MP40 along

with its software was used. The recording obtained is the graphical display of frequency versus amplitude of the EEG waves.

II. RELATED WORK:

Researches reveals that there are not a lot of methods for the treatment of Hypohidrosis, a very few treatments are available. The two ways in which Hypohidrosis is being treated are therapies and medications. There are numerous side effects of using medicinal drugs like prednisolone and steroid therapy that lead to hyperglycemia, weakness of muscles, stomach-based ulcers, and hypertension. Naz et al., proposed an Arduino-based device that uses a thermoelectric cooler. It operates on the Peltier effect concept to treat a sweating disease for patients with hypohidrosis and anhidrosis sweating conditions. [14]. Some devices have also been used that decrease the body temperature to some extent via the transmission of impulses to the body of the patient in order to maintain body temperature [15]. Moreover, cooling jackets are also used by patients suffering from hyperthermia and Hypohidrosis. Sabarish and Reddy developed a solar-powered thermal jacket that provides improved protection for anyone working in harsh weather. It employed peltier plate with a 500mA, 5V supply for effectively combating the high and low temperatures. A flat-plate solar panel will provide the energy needed to operate this peltier plate. The energy is stored in a lead acid rechargeable battery with a direct current output of 12 V[16],

The study by Linlin Cao et al., develops an innovative cooling helmet that simultaneously cools the head and neck of a person through water and air cooling mechanism along with thermoelectric refrigeration . The cooling effect of various environmental and human body cooling conditions, such as environmental temperature, input power, fan speed, and circulating water velocity, on the helmet is experimentally studied using an environment simulation device and a self-made thermal manikin. The findings indicate that the temperature of the surrounding air significantly affects the cooling properties of the helmet. By altering the helmet operation parameter, the helmet can satisfy the cooling requirement in a hot environment[17].

Hemavani et al., introduced thermoelectric cooler (TEC)/ heater suit by using TEC, a heat exchanger, and a motor to circulate water throughout the vest, and microcontroller technology to measure the suit's internal temperature. The strategy is to construct a TEC-based garment that allows the wearer to regulate and keep an eye on the temperature using controls and thermoelectric gadgets[18].

A researcher proposed the concept of Thermoelectric refrigerator which automatically maintain temperatures between 5oC and 9oC degrees through thermoelectric module. Atmel microcontroller is used to operate the device. The refrigerator's temperature is tracked and read using a temperature sensor. This gadget makes it simple to heat water during the winter. Moreover, the hot side's temperature is declined through multiple fans in the design [19].

Furthermore, all these devices are restricted to some area, however, one of the significant pulse point of wrist is ignored. Keep this in mind, we proposed a wrist band based cooling device that can give desirable outcomes by efficiently lowering the body to a great extent. The external environment and body temperature will be sensed, their difference will be calculated. The thermoelectric cooler is capable of producing a heat flux as the voltage source gets connected to its junction; this generates heat on one side of the thermoelectric cooler and cooling on the other side. This device works like a homeostatic control system by cooling the body temperature whenever it will be sensed above the normal body temperature. Moreover, the key feature of our design is the monitoring of brain condition during the process of lowering the body temperature through cooling mechanism.

Hypohidrosis is one of the leading problems, a condition that results in less sweating than required by the body. The increase in the internal temperature of the body due to the failure of sweat gland functionality is extremely dangerous and may lead to death[20]. Sufferers of hypohidrosis can have disorders of the skin, dyshidrotic eczema, ectodermal dysplasia, autonomic dysfunction, and varied medicines and toxin agents are accountable for the loss of sweating. To lower hypohidrosis various techniques and devices are used including solar-powered thermal jackets which are worn at extremely cold temperatures to keep the body warm, this Peltier device is a heat pump when voltage is applied, dc current flows through the two sides of the device from cooling plate side heat is absorbed and moved to the other side where the heat sink dissipates the heat from the device making one side hotter and other side cooler but this device is restricted to extreme temperatures [21]. The wearable bracelets also regulate body temperature through thermal pulses [22]. The temperature programmable suit provides a comfortable environment for the person where pipes are connected throughout the vest which helps in circulating the water, and the thermoelectric cooler (TEC) attached to the suit helps to cool the water [23].

III. PROPOSED METHODOLOGY:

3.1 System Description

The proposed device includes different components that are controlled through the programming of Arduino UNO [24]. As we integrate two LM35 temperature sensors into Arduino UNO, the first LM35 temperature sensor measures the body temperature, and the second LM35 temperature sensor measures the atmospheric temperature. As the normal human body temperature is 37°C [25], so the temperature sensor attached to the skin senses the body temperature and sends its data to the relay which is connected to the

thermoelectric cooler (TEC). The working of TEC is controlled through Arduino coding that is whenever the body temperature is greater than a predefined value which is 37.8°C, the output pin of Arduino sends a signal to the relay after which the relay becomes normally open and starts TEC functionality. TEC is powered through a 9v battery. When TEC becomes powered ON it starts the cooling process, the cooling side of TEC is integrated into the body which transfers the heat from the body to the heating side to make the body cool and the heating side of TEC will eject that excessive heat of the body and transferred it into the atmosphere. During this process, EEG recordings of the individual are also recorded using Biopac Lab software [26], we integrate the three basic electrodes and then from the software record the frequency of alpha, beta delta, and theta. Firstly, the EEG recordings of an individual are taken without a device (when the device is not working) in two conditions eye close and eye open, then the device is switched ON and starts its functionality to maintain the predefined temperature, at the same time EEG recordings of the individual with an eye close and eye open are again recorded to depict the difference in various waves of brain activity.

A. Block Diagram

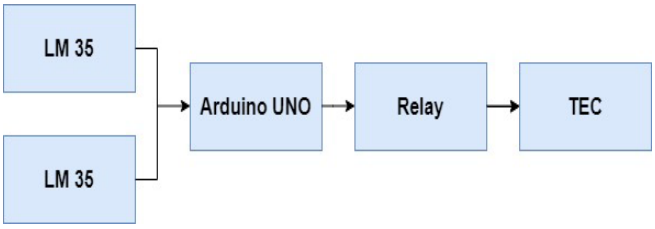

Fig 1. Block Diagram of the Device

B. Flow Chart

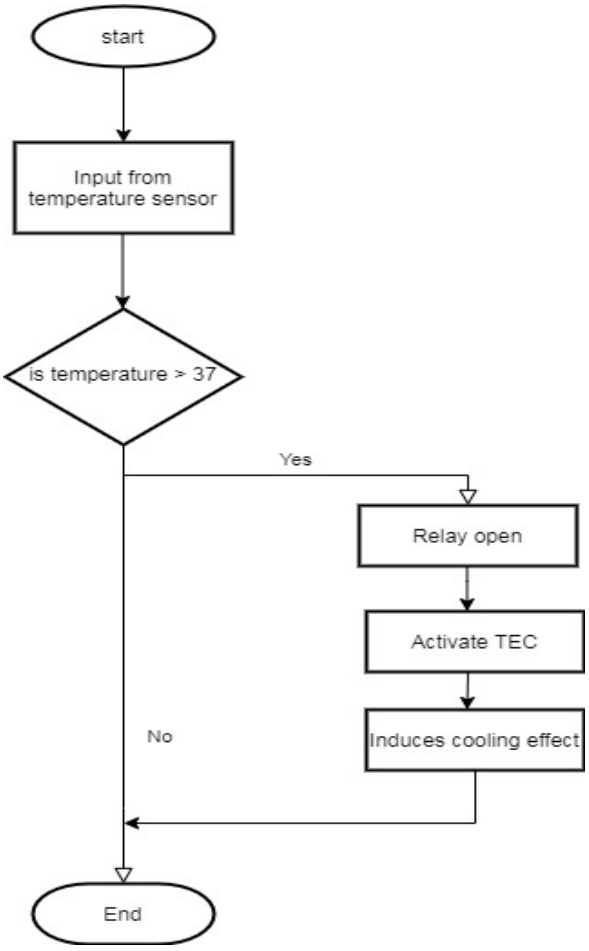

Fig 2. Flow Chart showing working of the Device

3.2 Electrode Placement:

For the collection of EEG, disposable vinyl electrode, and 3 electrode leads are used that are connected with the MP40 Biopac. Electrode leads are color-coded with red, white, and black where black lead is ground and red and white collect signals between the area of their placement. For the connection of leads, attached to disposable electrodes on the subject white lead is placed 4cm to 5cm behind the top of the ear, and red lead is attached on side of the head 4cm to 5cm above the first electrode and the black lead is attached to the ear lobe with the adhesive part folded under the ear to secure it [27].

IV. RESULTS

To test and validate the performance of the proposed energy management system algorithm, MATLAB/Simulink software environment is used. The residential microgrid load, parameters and renewable resources data modelled and used as a benchmark to test and validated the energy management system are adapted from.

Fluctuations in the EEG waveforms are observed with the participants who are wearing the device that differs from the EEG patterns of the ones who are not using the device for Hypohidrosis.

Furthermore, the relationship between the voltage of TEC and temperature is observed. The voltage of the thermoelectric cooler is inversely proportional to the changes produced in temperature as illustrated in Table 1.

Table 1: TEC Voltage and current variation in parallel with cold side temperature

TEC Voltage (V)	TEC Current (A)	Cold side Temperature (ºC)
3	0.85	16
4.5	1.25	11
6.5	2	3.5
10	3.1	2.8
11.5	3.2	2.6
12	3.3	2.4

Whenever there is a rise in the body temperature with reference to the atmospheric temperature, the voltage of the thermoelectric cooler decreases leading to a rise in the temperature of the cooling area of TEC, portrayed in Fig.3.

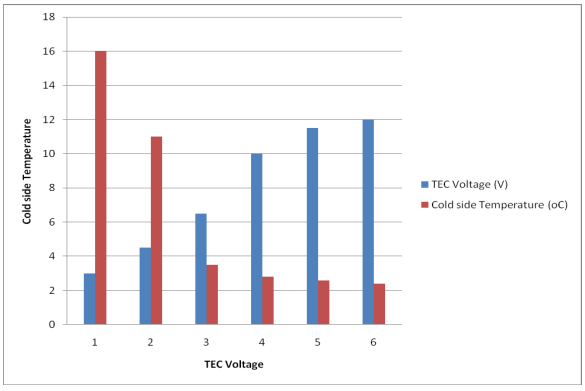

Fig 3: Bar graph depicting inverse relation b/w TEC Voltage and cold side Temperature

The time taken for the thermoelectric cooler for creating a cooling impact relies upon applied voltage; the cooling effect time is decreased as the voltage is increased. Fig. 4. depicts the change in temperature with the passage of cooling time.

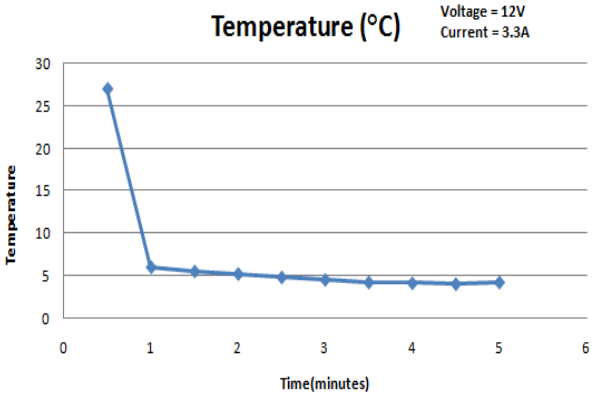

Fig 4:Relation b/w Temperature and time at a fixed voltage

TEC gives additional cooling in a more limited timeframe when the applied voltage progressively expands

EEG Waveform Recording obtained from Biopac Lab Software:

The given figures (Fig. 5-8) show the electrical activity of the neuronal network of the brain. Fig 5. shows the EEG waveform of a participant without a device with the Eyes closed. It is obvious from the recording that the alpha waves and beta waves have higher frequency with more amplitude as compared to delta and theta waves.

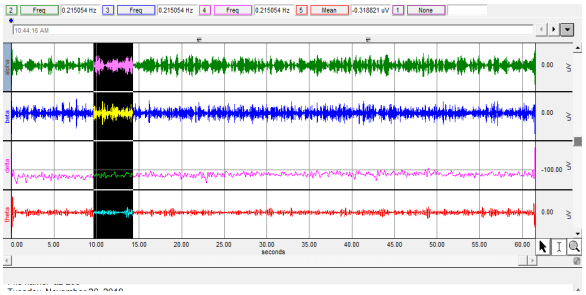

Fig.5: EEG waveform of a participant without the proposed homeostatic device with the Eyes closed state

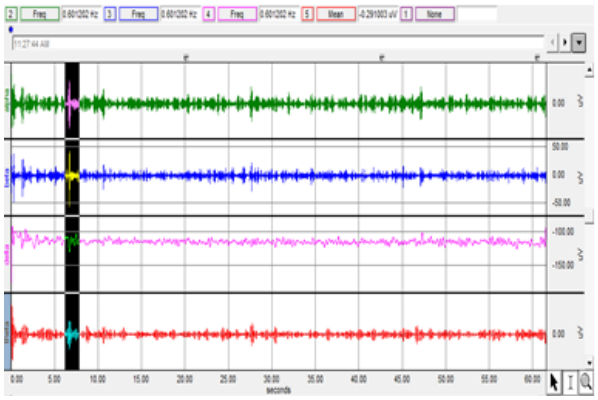

Fig 6: EEG waveform of a participant with the proposed homeostatic device with the Eyes closed state

Fig 6. shows the recording of EEG with eyes closed state when the proposed homeostatic device is switched ON with alpha waves as the most dominant waveform in terms of frequency and amplitude in comparison with the rest of the three waveforms.

Depth comparison of fig 5 and fig 6 reveals that with the proposed device, more precise alpha waves are obtained as the body is regaining the normal temperature when the eyes are closed.

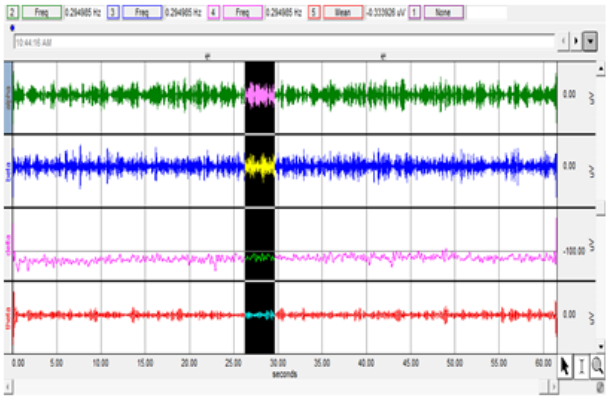

Fig 7: EEG waveform of a participant without the proposed homeostatic device with the Eyes open state

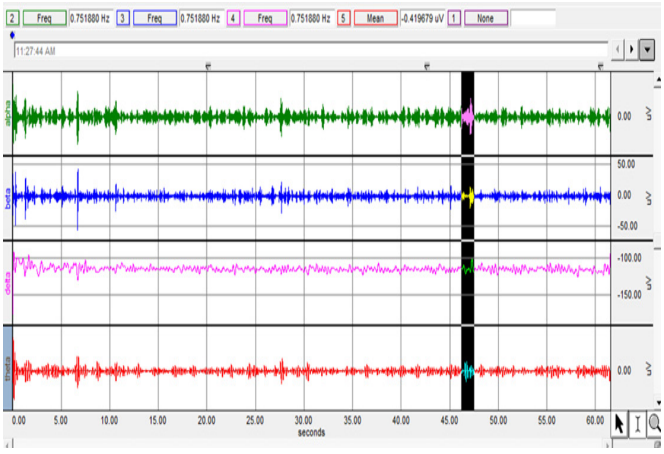

Fig 8: EEG waveform of a participant with the proposed homeostatic device with the Eyes open state

Figure 7 and 8 indicates the Eye open state without and with the proposed device. The outcome indicates that the alpha waves in presence of the proposed cooling device are better in terms of frequency and amplitude. Moreover, the submissive nature of theta and delta waveforms in all the figures is related to the waking state of the participant as these waveforms are more clear during sleep.

V. CONCLUSION

The device of Hypohidrosis is to provide the user with the desired comfort, ease along with mobility. It is a device that can be easily afforded by the patients and its usage is of immense importance for lowering the body temperature whenever it rises beyond the body temperature and generates excessive heat in the body. The condition of Hypohidrosis can be significantly resolved with the help of a Thermoelectric cooler. The voltage of the thermoelectric cooler is inversely proportional to the variation in temperature, therefore as the body temperature rises with reference to the temperature of the atmosphere than the voltage of the thermoelectric cooler decreases. In addition to it, changes in EEG waveform are observed in patients with the presence of a Hypohidrosis device and without the device.

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