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Peltier Elements-based Human Brain Hypothermia Treatment

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Abstract

Cooling and hypothermia of the brain is an important and effective way to save the lives of many patients suffering from diseases such as strokes, epilepsy, incurable diseases, and others due to general accidents. Brain cells are also weak and sensitive to changes and fluctuations in human temperature. In this work, a hypothermia device was designed and practically implemented to reduce the brain and body temperature. It mainly consists of temperature sensors for measuring water and patient temperature, a Helmet made of plastic tubes with a thermal coefficient suitable for absorbing heat, cold water is circulated inside the tubes to cool the head, and the cooling is done through Peltier elements in the device. The Arduino microcontroller controls the system. The experimental results showed a decreasing in brain temperature to 36.5 °C within a cooling time of 12 minutes. The effectiveness of the proposed system was also validated by comparing the findings with the previous system in terms of temperature and cooling time.

Publisher : Middle Technical University

Keywords: Arduino Microcontroller; Helmet; Hypothermia Brain; Peltier; Temperature Sensor.

1. Introduction

Brain temperature is a crucial matter that has not been studied in depth because high temperature makes the patient's condition terrible, and because it is the main factor for the health and functions of the human body [1, 2], a meaningful, vital sign that there is no problem in the human body [3]. About 17.9 million people worldwide die annually, according to World Health Organization (WHO) statistics, from many chronic diseases, of which about 85% are due to heart attacks and acute strokes [4]. The delay and negligence in lowering the temperature of the brain lead to severe bleeding and damage to brain cells [5, 6]. Strokes suffered by the patient are the second cause of death for the patient after myocardial infarction, according to mortality statistics for the world population. Due to a sharp rise in brain temperature, damage to blood vessels and brain cells, and nausea. Several methods reduce the brain's temperature therapeutically, called invasive methods, namely the intravenous catheter operated by the surgical intervention [7]. Methods Non-surgical hypothermia is a bag of ice and cold air [8]. Many scientists have come up with solutions to the problem of high brain temperature by designing, manufacturing, and developing many devices that help the patient save his life and reduce brain damage by cooling the brain [9]. Kim et al. [10] invented an effective way to reduce the body temperature of newborns during Childbirth by taking advantage of the phenomenon of evaporation and the interaction of heat absorption. Mardar and Cojocaru [11] proposed the design of a device to reduce and cool the body temperature. They used Peltier elements, a flexible control algorithm based on fuzzy logic in maintaining a low temperature. Gruba et al. [5] designed a non-invasive device to reduce brain temperature and treat stroke and hyperthermia in the brain. It depends on thermal energy. Hassan et al. [12] designed a system for measuring brain temperature. Thermal cooling elements have been used and installed inside the Helmet and are a cooling method. Ahıska et al. [13] designed the Human Brain Hypothermia System (HBHS). The system is intended for cooling and heating the brain which relies on microcontrollers. Imoto et al. [14] designed a modern cooling system that uses thermoelectric Peltier element chips to reduce the brain's temperature.

Kaimas et al. [15] designed and developed a cooling system to reduce head temperature using a thermoelectric Helmet. Otsuki et al. [16] developed an air-cooling system to reduce brain temperature based on a fuzzy logic control algorithm [3]. They developed a non-invasive body temperature reduction system using a Peltier element to reduce the incidence of Stroke. Magnoni et al. [17] designed a device to cool the brain through an external cooling collar placed on the surface of the patient's neck to calm the tributaries of the arterioles to the brain. Hermann et al. [18] developed a technique for cooling blood in the brain through intravascular catheters to treat acute Stroke. Yavuz [9] designed a Helmet to reduce brain temperature and brain cell damage during strokes or strokes by cooling brain cells. Huber et al. [19] developed a study to cool the blood and lower the brain temperature of stroke patients through catheters by injecting cold saline into the internal jugular vein, which carries blood from the head and transports it through the superior vena cava to the heart - and comparing the temperature with the carotid artery. The challenges found in developing these devices affect patient safety, such as rapid hypothermia in the body and brain, causing vascular trauma to the patient, or causing a patient skin burn from freezing. The cold is caused by the cooling element inside the Helmet [20], as several types of Helmets were manufactured that reduce the brain's temperature. However, several defects were found in them, such as temperature instability and short cooling time due to the environment. The impact on energy efficiency is low; Helmets lack the flexibility to wear, have small volume, and have poor cooling efficiency [8].

Nomenclature			
WHO	World Health Organization	HBHS	Human Brain Hypothermia System
NTC	Negative Temperature Coefficient	LCD	Liquid Crystal Display

In this research, a device was designed to reduce brain temperature by developing a head-cooling Helmet with lightweight plastic tubes and good thermal conductivity to the skin. Fitted hierarchically to fit all head sizes. The Helmet is cooled through a closed water cycle, and cold water is passed inside the Helmet. The system generally consists of an Arduino controller to control water temperature, a Helmet for cooling the head, sensors for measuring water temperature and patient temperature, Peltiers cooling elements for water cooling, a DC power supply, a fan, and a radiator to eliminate the heat generated by the Peltier and the device, and an LCD to display the temperature reading. The general results on the device in general and on the Helmet, in particular, showed a decrease in the patient's temperature in a short time, about 12 minutes, when the temperature was about 40 °C, as many tests were performed on the device in terms of measurement. The temperature of cold water inside the Helmet and cold water inside the tank in which water enters the Helmet to cool the patient and measures the temperature of the water system that cools based on Peltier elements.
The contribution of this study is summarized as follows:

1. The proposed system was practically implemented to reduce the brain's temperature in humans.
2. The results were practically obtained by measuring the patient's temperature and the device's efficiency.
3. The system's efficiency has been verified from the time required to reduce the temperature to alleviating challenges or obstacles.
4. The results of the previous works were compared with the proposed work to confirm the proposed system's efficiency.

2. Related works

In [5], a non-invasive brain hypothermia device was designed to treat stroke and hypothermia. The goal is to introduce an improved system for lowering body temperature by installing Peltier elements inside the helmet based on thermal energy. The device consists of a helmet consisting of Peltier elements, which absorb heat by the electric current on one side and transmit it to the other. The mechanism of the device is that water flows through the coolant forming a closed circuit powered by an electric pump. This circuit's function is to cool the hot part of the Peltier element. The cooling efficiency is directly affected by the temperature of the water from the circuit. When the water temperature drops, more heat is absorbed. The elements are mounted on an adjustable helmet that adapts to the size of the human head. The arrangement of the elements in the helmet is highly dependent on the areas where low temperatures travel without significant brain losses. One of the advantages of the device is that it is light in weight and low in cost. One of its disadvantages is that it is affected by ambient temperature.
Hassan et al.[12]. designed a system for measuring brain temperature. Peltier Thermo cooling elements have been used and installed inside a helmet and are a cooling method. The heat from the hot part of the pellet is cooled using circulating water to provide a long operating time and system cooling. The device consists of a Peltier main cooling element, a temperature sensor (NTC) to collect the patient's temperature in four places, an Arduino controller to control the work of the device, and a Raspberry for image and data processing. The temperature reading accuracy depends on the value of the NTC resistance and its matching with the exact value of the known resistor to create the voltage divider. Therefore, a 20K variable resistor was used to set its value to the desired resistance using a millimetre. The work of the device showed that the helmet is flexible, weighs about 1,275 kg, and is suitable for all ages. The water regime was maintained at a continuous cooling rate for 12-72 hours.
Giuliani et al. [17] A non-invasive device has been created to control the brain's temperature by manufacturing a cooling compressed collar with a flexible external. A cooling collar was placed on the patient's neck to reduce pressure and temperature on the arterial tributaries leading to the patient's brain. The goals of the device were to control the lowering of blood temperature through the arteries connected to the patient's head. The device shall consist of a temperature-regulating collar and be attached to the cooling time specified. The device was first applied to a group of adult sheep because the animals' skin is resistant to low temperatures and contains lanolin. The initial results on the sheep group showed a similarity between the body and neck temperature, as the brain temperature during (100 minutes) decreased to 36.5 degrees Celsius, and the human body was 37.5 degrees Celsius, where the average of the experiment was between 35.5 and 37 degrees Celsius. The device can lower the temperature by up to 5% (5 °C) to prevent local freezing. The device is light in weight, easy to carry, and attractive in terms of shape. It can be attached to any place in the body, whether in the hand or the leg, and it is separate from it, and it can be used in hospitals and used to treat fever. The disadvantages and challenges of the device are that it freezes in the exact location where the collar is attached, which leads to blood clotting.
Cattaneo et al. [18] developed a technique for cooling blood in the brain through intravascular catheters to treat acute Stroke. The catheter placed a cooled saline solution inside the blood vessels to treat acute Stroke and intravascular clots. The main goal of the blood cooling technique is to speed up the removal of clots inside the blood vessels. The experiment was carried out on a group of sheep, where the cerebral artery was closed for some time, after which the catheterization was done through the nose and angiography. The results showed that the blood temperature inside the vessels decreased by one °C to three per hour after 3 hours after using the catheter. The use of catheters is safe and does not indicate tissue damage.
In [19], blood cooling was studied for patients with Stroke and heart disease through catheterization, which is the injection of cold saline solution into a vein that transports blood to the brain. The study experimented with a group of mice where the cerebral artery had been closed for some time, and a cooling solution was infused into the artery. The results showed that the solution passed into the vein cooled the blood by a large percentage and quickly, as the temperature dropped to 34°C after 60 minutes. The study showed that catheterization in the blood vessels is quick and inexpensive in reducing body temperature. This method is used in surgical operations to reduce the temperature quickly
In [21], the authors developed a study of the selective cooling of the brain and rapid hypothermia employing the Neuro Save system, which is the infusion of cold saline solution into the oesophagus. The system consists of essential components related to the patient and can quickly dispose of tubes, a fluid reservoir, two filters, and a heat exchanger. This system showed a decreased brain temperature by three °C within 15 minutes. The advantages of the system are fast decline in temperature. However, the challenges were disappointing due to the presence of several problems, including the effect of the rapid drop on the arteries connected to the heart. In [22], the authors designed a helmet to cool the head, which aims to reduce the head's temperature by circulating cold air inside the helmet using Peltier elements. The helmet consists of Peltier elements, a battery, a heat sink, and a fan to circulate the air inside the helmet. The practical results on the helmet showed good efficiency and a decrease in temperature by two °C per hour. The device is lightweight, easy to carry, and generally low-cost. Mazalan et al. [23] designed a

well-known commercial helmet, which was designed from a material called polyester. Its purpose is to cool the head and reduce the brain's temperature. The head was covered from front to back for cooling. The helmet consists of holes in which a substance called crystal is filled. The helmet is soaked with water before the experiment to activate the crystal substance until it becomes a gel-shaped substance. It is placed at a coldness of 15 °C for four hours, after which it is worn. One of the disadvantages of the helmet is that it gives good results when shaving the head. The practical results showed a reduction in the temperature of the head by degrees°C .

Zambrano-Becerra et al. [24] presented a portable and easy-to-use cooling system by designing a helmet to cool the head. Its purpose is to reduce the temperature of the head and body in light of high temperatures. The helmet consists of Peltier elements and holes for ventilation and heat exchange between the helmet and the Peltier element. The Peltier was used as it is easy to use and light in weight. The practical results on the helmet showed an apparent decrease in the head's temperature. One of the disadvantages of the helmet is that it cools certain parts of the head, and the presence of openings and heat exchange causes discomfort to the person wearing the helmet. Eldho et al. [25] developed a helmet and jacket for cooling and lowering body and head temperatures. The study's objective was to reduce the temperature and control the heat in the outer perimeter. The jacket and helmet consist of Peltier elements and fans, and the pellet's heated part is cooled through the outer perimeter. The helmet and jacket are coated with an insulating material called polyethene that allows heat distribution. These materials are considered few. The cost is relative. The practical results were conducted within a climatic environment where the temperature of 30°C decreased when wearing the helmet and jacket to 22°C. Hu et al. [26] suggested a cooling helmet dedicated to the head. The study's objectives were to design a cooling helmet suitable for workers and people. The helmet consists of a PCM material that absorbs heat, and a fan was tested using three helmets; the first was expected, the second was with the fan, and the third was covered with thermal absorption material PCM. Experimental results under high temperatures showed that the heat-absorbing helmet has the advantage of absorbing heat to achieve a cooling system. The temperature inside the helmet was 27 °C for 120 minutes. One of the disadvantages of the heat-absorbing helmet is that it is not good in terms of ventilation, as the scalp sweats and causes discomfort to the person.

The challenges facing the study are that pumping the cold saline solution leads to a decrease in the size of the artery and the study's lack of randomness, as the animals differ in weight and age. From the articles mentioned above, we can deduce some challenges and limitations related to the manufacture and development of the Helmet designed and reduced temperature as follows:

1. The rapid drop in brain temperature causes vascular shock and convulsions, which causes death.
2. Skin burns result from direct contact between the cooling element and the skin due to severe cold.
3. The heavy weight of the Helmet, as the Helmet weight was found to be 5 kg in some research work, causes pain in the patient's head [3].
4. The Helmet size is significant due to the cooling elements, ballistics, and fans inside the Helmet.
5. Long period to reduce the temperature of the brain, as the duration of time was found to be about three hours in some cases for reducing the temperature.

3. Methods and Material

3.1. System Design

Our proposed system consists of several essential parts: Helmet, Peltier cooling, power supply (DC power supply), Arduino, pump, radiator, fan, sensors temperature, insulation, relays, and LCD monitor. Before starting the mechanism of the device, the temperature of the water in the cold-water tank should be about 25°C, after which the Helmet is attached to the patient, and the temperature sensor is attached to the patient. The device's duration depends on the patient according to the patient's temperature until the desired temperature is reached. The idea of the device is that the device contains two systems, the first system is used for cold water going to the Helmet, and the second is for cooling the Peltiers. The device contains a cold-water tank and a pump that pushes cold water from the tank towards the Helmet, and the water leaving the Helmet returns towards the peltries system and returns to the tank again with a closed water cycle. Several sensors were placed to measure the water temperature inside the device and a sensor to measure the patient's temperature. The sensors are distributed inside the cold-water tank as follows. The first sensor was placed inside the water pipe going into the Helmet. At the same time, the second sensor was positioned inside the water pipe from the Helmet. The third sensor was located inside the radiator's water pipe. Whereas the fourth sensor was fixed inside the cold water. However, the last sensor was placed on the patient's body or head [22]. The block diagram shown in Figure 1 illustrates the main elements of the implemented device.

It is worth mentioning that the system was tested on Phantom. A bag of hot water was placed at a temperature of 41 degrees Celsius, the highest temperature the patient could tolerate. The temperature measurements were recorded, as seen later in the result section.

3.2. Helmet design

The primary goal of the device's design is to cool the head, reach the desired temperature, and preserve brain cells. One component of the hypothermia device is Helmet. The Helmet was manufactured hierarchically by wrapping the plastic tube on the mechanics to take the shape of the patient's head. There are two entrances to the Helmet, an inlet for the entry of cold and an outlet for hot water and its return to the device. The Helmet tubes are designed in a plastic shape and are lightweight to facilitate wearing all head sizes. Cold water passes inside the tubes to cool the head. There is a sensor inside the Helmet to measure the temperature of the water entering the Helmet and the water leaving the Helmet [3, 5, 15]. Fig. 2 shows the Helmet design side, front, and inside view.

3.3. Hardware Platform

- Peltier cooling :A Peltier is a device that converts electrical energy into heat energy [27]. It contains two sides, one side is hot, and the other side is cold. The unit works as a heat pump, transferring heat from the cold side to the hot side. This device connected eight units in a series connection method to reduce the current draw [28]. A closed water system was connected to continuously remove heat from the hot side so that the device works efficiently and correctly. The current draw of the single voltage of the voltaic is about 10 amperes, and it operates on 12 or 24 volts [27-30].

- Controller: The Arduino microcontroller is this system's primary and essential controller unit in terms of processing the data sent by temperature sensors to the Arduino and converting it from a standard signal to a digital signal displayed on display. The Operating voltage of the Arduino microcontroller is 5 volts [12].
- Temperature sensor: A digital temperature sensor was employed to measure the water and patient temperatures. Type DS18B20 was considered for these measurements. The cable is about 100 cm long and works with 3 or 5 volts [31, 32].
- Relay: It is an electrical switch activated by an electrical signal to control the operation of the device. In the proposed system, seven relays were used to control the operation of peltries and other components. The power supply of these relays is 5 volts and can pass 10 Amp through contact. Four are used to control the work of Peltier's' system. The rest are distributed as follows; the fifth relay for the cold water pump, the sixth relay for the hot water pump, and the seventh relay for Fan [33].

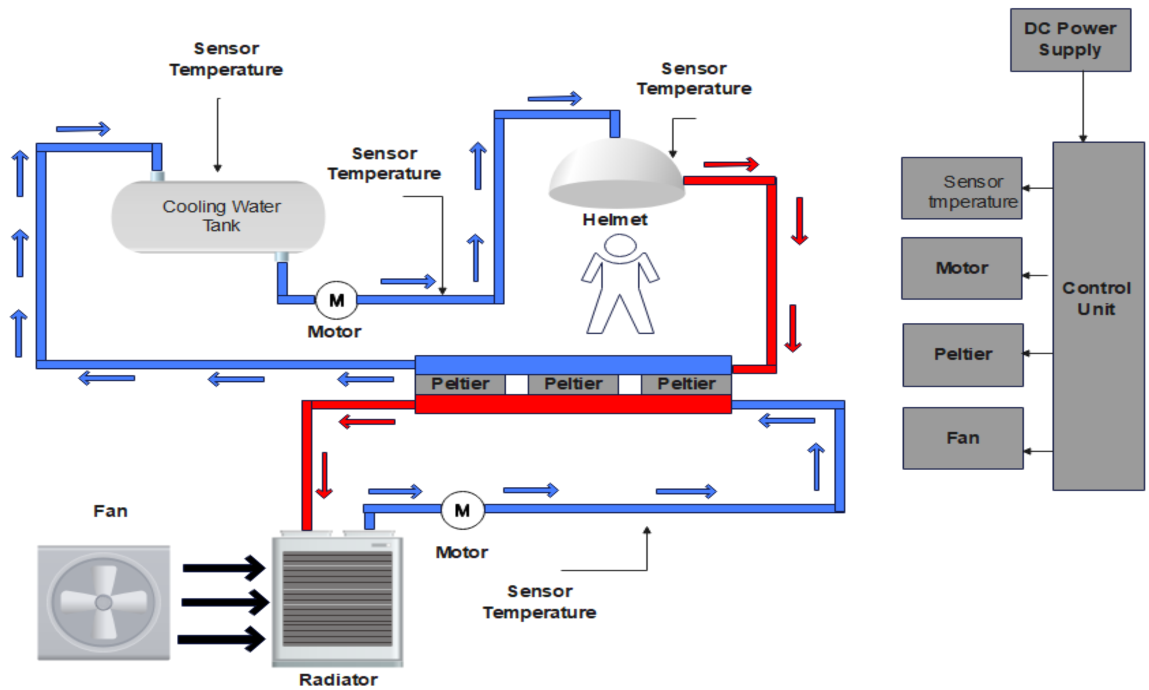


Fig. 1. Block diagram of the hypothermia device

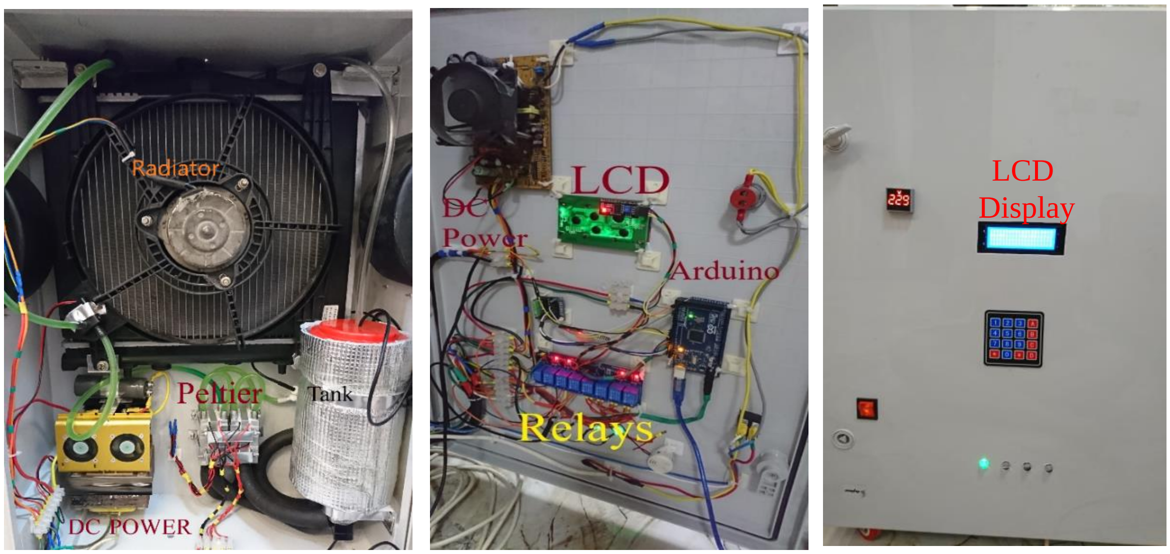
(a) (b) (c)

Fig. 2. Helmet cool (a) side view (b) front view (c) inside the Helmet

- LCD monitor: The LCD is used to display the measured temperature of the water based on sensors in cold and hot water and to display the measured patient's temperature.
- Pumps: It is a pumping system used to drive water. It is designed to prevent leakage, works for extended operating periods, is small in size, is quiet during the operating period, raises water to 3 meters, and has a flow rate of 240 liters per hour. There are two pumps in the system, the first is used to drive cold water to the Helmet, and the second is to drive hot water from the Helmet to the tank to cool it and return it to the Helmet. It works with 12 volts and drains a current of 300 mA [34].
- Radiator: The radiator is a water cooler made of aluminium, designed in the form of tubes, including aluminium strips, to increase cooling efficiency and the life of the device. Use a large-sized coolant with a diameter of 43 × 40 and a depth of 5 cm as a water tank, and at the same time, cool the Peltier system. It was used in this system to dissipate heat and cool the hot side generated by the Peltier thermoelectric cooler [35].
- Fan: The system cooling fan is an essential part of this device. The fan is connected to the radiator to draw and distribute air and eliminate the heat generated from the radiator and the device. The fan operates at 5 volts and a current of 1.72 Amps. The fan dimensions were 40 cm in width and 35 cm in height.
- Tank: It is a 2 liters basin covered from the outside with a heat-insulating material used to store cold water.

- Insulation: They are tubes wrapped with insulating hoses made of rubber, which were used to prevent the loss of cold water entering the Helmet, protect the device from the heat of external influences, and keep the water cool for as long as possible.
- Power supply: It is a source of electrical energy for the device, where two devices have been installed, and they are equipped with mechanical parts with a voltage of 24 volts, a high current of 100 amperes, and a capacity for electronic parts with multiple voltages of 12 volts and five volts, and a current of five amps. The device works as the primary source of electricity. 220 volts.

Fig. 3 shows a snapshot of the device's parts, including external and internal components.



(a) (b) (c)

Fig. 3. Snapshots of the device (a) internal parts of the cooling system, (c) control parts of the system, and (d) front panel of the system

3.4. Software framework

The Arduino software achieved patient temperature measurements based on the DS18B20 sensor. The Arduino program starts reading the input of temperature values. Then, the connection of the relays with the microcontroller was defined as well as the LCD. The program code consists of several libraries, including the Wire One library and Dallas temperature library for temperature measurement in Fahrenheit or Celsius. In addition, they communicated the temperature data with the microcontroller. The LCD library was used to set the LCD connection with the microcontroller. The I2C library is employed to enable the serial connection with the microcontroller. The role of the relay is to control the peltries by turning them on or off. The sensors that were used to measure the temperature are as follows:

- T1 sensor to measure the temperature of the input water to the Helmet.
- T2 sensor to measure the temperature of the cold water.
- T3 sensor to measure the temperature of the radiator.
- T4 sensor to measure the temperature of the output water from the Helmet.
- PT sensor to measure the temperature of the patient.

When the temperature of the cold water T2 is between 31°C and 50°C, all eight peltries work to cool the water entering the Helmet. Only six peltries work when a cold temperature is reached between 31°C to 27°C to cool the water. Four peltries work when the temperature drops between 27°C to 25 °C. However, only two peltries work when the water reaches a degree of cold between 25 °C and 23°C. On the contrary, once the degree of coldness reaches 23°C, all the peltries stop working. The flowchart of the operation algorithm of the system is shown in Fig. 4 .

3.5. Experiment Configuration

In this experiment, the effectiveness of the device and its ability to cool the water delivered to the patient and the device's ability to withstand the high heat generated by the device parts and the hot part of the Peltier elements were examined. The test was done by running the device without turning on the fan and knowing the time required to cool the water. Then the test was conducted to check the water inside the cold tank connected to the helmet, where a quantity of hot water of up to 2 liters was placed in the tank. The water temperature was 41 degrees Celsius to know the time required to cool the cold water reaching the helmet. Then the helmet was examined and tested, and its efficiency in reducing the temperature of the brain utilizing the Phantom, where a bag of hot water was placed at a temperature of 41 degrees Celsius according to the patient's temperature and time test required to lower the patient's temperature. Fig. 5 shows the mechanism of checking and testing the patient's temperature.

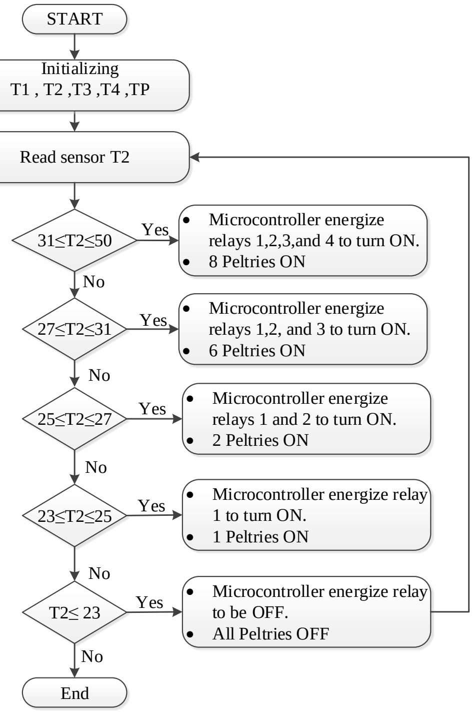
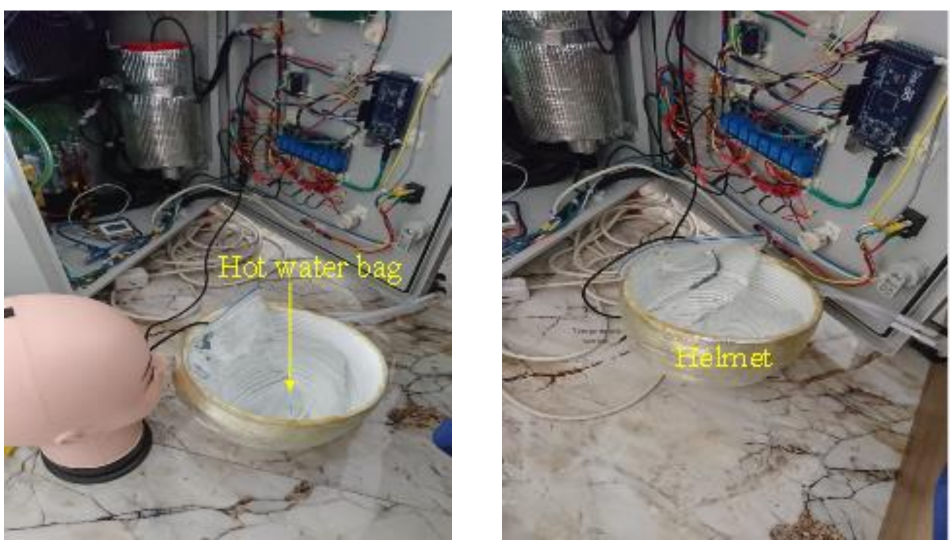


Fig. 4. Flow Chart of operation algorithm

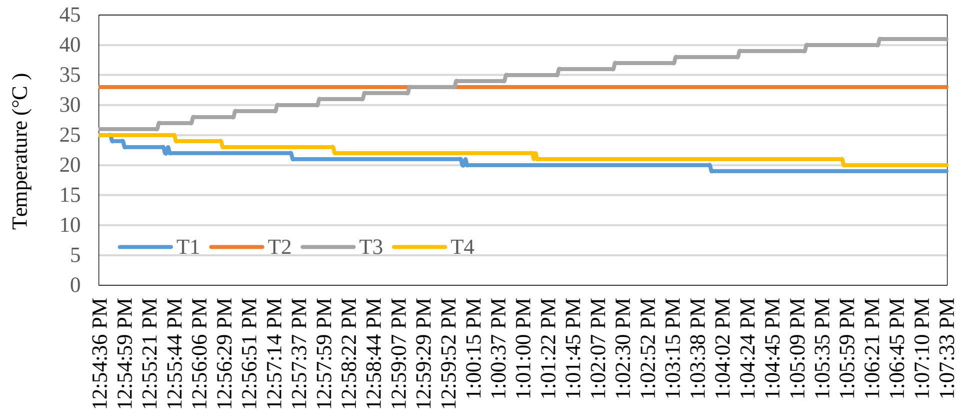


(a) (b)

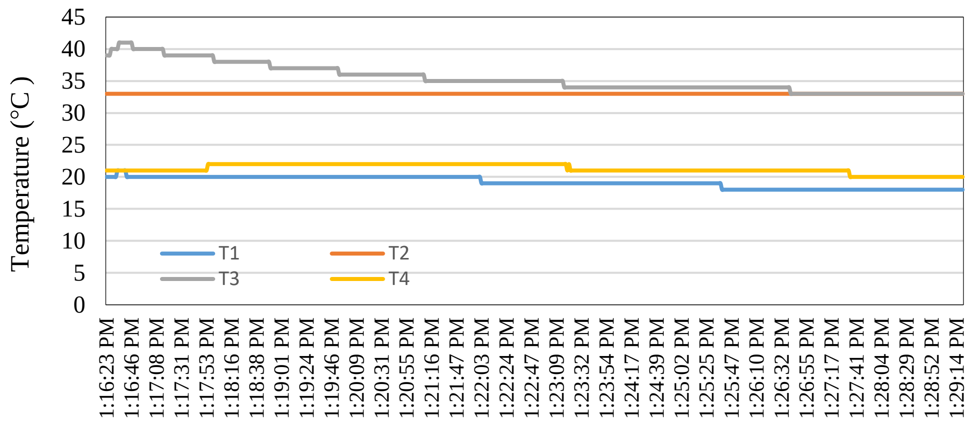
Fig. 5. Snapshot of the experiment

4. Results and Discussion

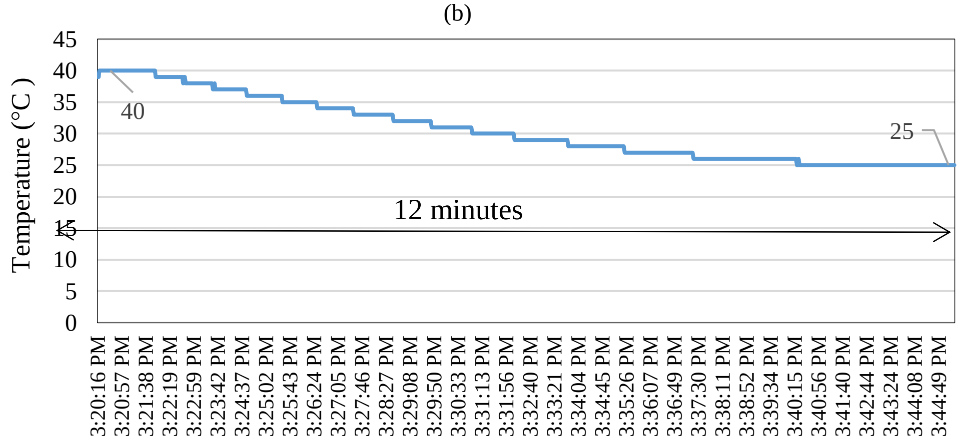
After conducting tests for the device's ability to reduce the temperature through several experiments, where at first the device was run at total capacity, in terms of the work of all the Peltier without the fan working to cool the device and to cool the heat generated by the Peltier, to know the duration of time for the temperature to rise, and the benefit of the fan in cooling water inside the radiator, the results showed that the rise time was about 12 minutes, that is, 1°C rise every minute, after that the device was tested, and the temperature was measured by running the fan to reduce the temperature, the temperature was descending 1°C every minute. Figures 6a and 6b show the process of high and low temperatures, respectively.



(a)



(b)



(c)

Fig. 6. Radiator temperature test results (a) up the temperature, (b) heat drop, and (c) cold water

A sensor was placed to measure the coldness of the water in the cold-water tank and to know when the water had cooled down and reached the desired temperature, where we wanted the cold-water temperature to be in the tank at 25 ° C. A quantity of about two liters of water was placed in the cold-water tank, and the sensor was placed inside the tank. The results showed that the time it takes for the water to reach the required temperature of 25°C is 12 minutes, that is, 1°C per minute. Fig. 7 shows the degree of the patient's temperature test. Where a hot water bag with a temperature of 42°C. Then, the test was conducted to check the cold-water tank by placing a sensor to measure the temperature of the cold water in the tank and to find out when the water got cold and reached the required temperature, as we wanted the cold-water temperature in the tank to be 25°C. A quantity of about two liters of water was placed in the cold-water tank, and the sensor was placed inside the tank. The results showed that the time it takes for the water to reach the required temperature of 25°C is 12 minutes, that is, 1°C per minute. Fig. 7 shows the degree of the patient's temperature test. A hot water bag with a temperature of 42 °C was placed inside the helmet as the temperature of the brain, and the patient's temperature sensor was placed inside the helmet, and the test was done. The results showed a decrease in the helmet's temperature from 40 °C to 36 °C for approximately 12 minutes [36]. Fig. 7 shows the patient's temperature test score.

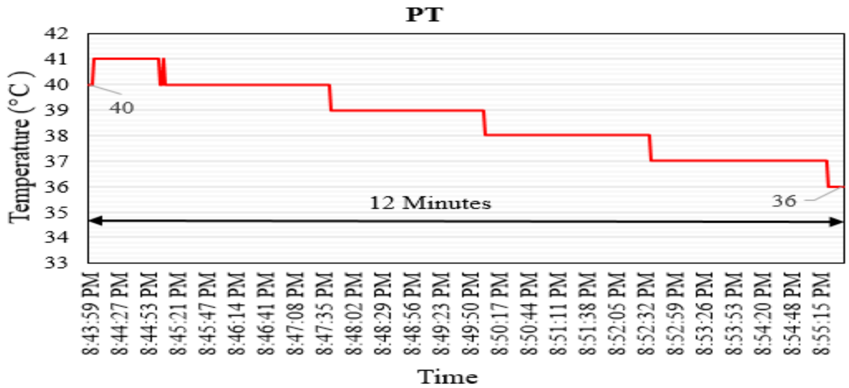


Fig. 7. Patient's temperature test score

6. Comparison Results

The proposed system was compared with the previous systems. It was found that the proposed system is characterized by easy access to the appropriate temperature in a short time. As a helmet of PVC pipes with excellent heat, the coefficient was used to deliver the appropriate coolness to the head. When the device was tested on a hot water bag with a high temperature of 43 °C, the highest a patient can reach, the hot water bag was placed inside the helmet. A decrease in the water temperature to the required degree is observed without water freezing.

Table 1. Comparison of previous works for HBH

Ref./year	Adopted method	Sensor Type	Sensor location	Time-consuming (min)	Temperature up to (°C)
[17] /2016	utilizing compact collar	Temperature sensor	Neck	100	36.5
[5] /2018	Helmet Water pipes Heat sink Peltier	Temperature sensor	Brain	15	5
[21]2019	intravascular catheters	Cold saline	Brain	60-90	34
[19] 2020	intravascular catheters	cold saline	Brain	60	35
[12] /2021	Peltier, Helmet	Temp sensor	Brain	60	35
[18]2021	intravascular catheters		Brain	180	35
This work	Helmet Water pipes Peltier	Temperature sensor	Brain	12	36.5

7. Conclusions

The human brain hypothermia device has been designed and implemented in practice to reduce the brain's temperature by designing a helmet made of plastic tubes with an excellent cold coefficient of heat absorption. The results for the device were made by doing a test with heat, cold water in the tank, and water in the helmet. The tank temperature was fixed at 25 °C; Whether the device was working or not, the results showed that cold water reached the helmet in about 12 minutes, and the patient's temperature gradually reached 36.5 degrees Celsius in 12 minutes. The presented device achieved several goals, including quickly reducing the brain's temperature to the required level. The size of the helmet is suitable for all ages. The weight of the helmet is very light in terms of manufacturing, as it was about 250 grams because it is made of lightweight tubes and does not affect the patient's head, and controls the level of the flow of water inside the helmet, the safety and security of helmet wearing, and the ability of a device to communicate with more than one patient on the same device. Since the device is portable, it can be powered by a rechargeable battery. Future improvements to this system will focus on adding two sensors to measure heart rate and oxygen in the blood because the high temperature of the brain and body causes an increase in the heart rate and breathing rate, so it is possible to know the level of oxygen in the blood, and the speed of the heartbeat when the temperature drops. The device can also be supplied with solar energy for its ability to work with DC voltage. Moreover, the device can be connected to the Internet of Things system to monitor the patient anywhere and anytime.

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