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Bluetooth Module-Based Wearable Heatstroke Alert System Based on Physiological and Environmental Parameters for Agricultural Workers

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A B S T R A C T

Agricultural workers are often exposed to high temperatures in the field to do their jobs and they are among the most vulnerable to heat-related illnesses. Heatstroke is a severe case of hyperthermia in which the body temperature significantly increased due to excessive external heat or the physical effort of workers. Heatstroke can potentially be harmful to agricultural workers while working in hot environments. To avert this potentially fatal condition, a Wearable Heatstroke Alert System (WHSAS) was developed with early notification ability to avoid heatstroke while performing various agricultural activities in the field. The WHSAS is a Bluetooth module based android application. The simulation of the system is based on non-invasively real-time data such as body temperature, pulse, ambient temperature and humidity. The device was tested and compared with clinical standards for performance benchmarking. The developed device provides new opportunities to manage heat stress in open fields when agricultural workers are subjected to high temperatures and humidity. If an alarming situation is detected, then the device will activate the alert function to remind the user to act suitably to prevent heatstroke. The device also can be used as a research tool to study physiological responses under various environmental conditions, such as extreme heat, humidity etc., and can be customized to incorporate new sensors to explore other lines of inquiry.

Key words: Agricultural worker, Heat stress, Heatstroke, Physiological and meteorological parameters, Sensor

People's health worldwide is in jeopardy because of climate change, which increases the danger of occupational heat stress and affects an enormous workforce employed in a wide range of industries [1]. A temperature increase of 0.08 °C (0.14 %) each decade has occurred since 1880, and the rate of warming since 1981 has exceeded double that: Since 1981, the average annual increase in temperature has been 0.18 °C (0.32 °F) [2]. According to these data, the average global temperature has risen rapidly in the last few decades. Workplace productivity and health may be jeopardized because of local climate change-related fluctuations in air temperature and humidity [3-4]. Furthermore, even moderate changes in ambient temperatures could push large worker populations exposed to 'near limit values' of heat stress over the threshold into suffering heat stress-related health concerns [5]. Besides, the risk of occupational heat stress is expected to increase significantly in middle and low-income tropical and subtropical locations, where effective controls may be unavailable [6].

Apart from non-tropical, developed countries have researched the physiological repercussions of high thermal loads. But there have been few attempts in many developing nations like India to evaluate the health implications of occupational heat stress and even fewer to correlate heat stress to productivity losses [7]. Non-tropical developed countries have been the primary location for conducting heat stress tests and quantifying thermal loads and associated physiological effects. Few attempts have been made in developing nations like India to produce precise heat exposure profiles for different workforce sectors [8]. Thus, effective intervention measures become even more critical considering the current and future heat stress caused by climate change.

Most agricultural operations in the country are still carried out by hand. Farmers are frequently exposed to heat stress because of their outside agricultural activity [9]. Farm laborers perform strenuous labor regularly under adverse weather conditions. Knowledge of farmers' experiences with

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heat and climate change is necessary and critical for developing and implementing policies to protect them from climate change. Apart from high drudgery and low remuneration, the primary impediment to agricultural development is the lack of water. Plowing, sowing, intercultural activities, and harvesting are the primary agricultural operations carried out on hot sunny days; some of these operations are carried out with manual tools. India is characterized by significant seasonal temperature changes, ranging from a mean temperature of approximately 10 °C in the winter to approximately 32 °C in the summer season [10]. In March and April, temperatures begin to rise over the country; the interior regions of the Indian peninsula have mean daily temperatures of 30-35 °C. The central Indian landmass grows hot, with maximum daytime temperatures exceeding 40 °C [9, 11].

Heat stress develops when the body cannot release its surplus heat to the surrounding environment adequately. It has primarily been investigated in occupational settings where heat is employed in the manufacturing process (e.g., the steel and brickmaking industries), when opportunities for lowering heat exposure through work environment modification may exist [12]. Due to the outdoors nature of agriculture, such solutions are typically unavailable. To avoid heat stress, it is required to adapt work organization to the climatic conditions. Agricultural laborers who operate in hot conditions or are exposed to excessive heat are at risk of heat-related illness. Extreme heat exposure can cause workplace diseases and injuries. Heat stress can manifest itself in various ways, including heatstroke, heat exhaustion, heat cramps, and heat rashes.

Additionally, heat can raise the risk of injury for agricultural workers by causing sweaty hands, fogged-up safety glasses, and dizziness. Accidental contact with hot surfaces or steam can also result in burns. Workers 65 years of age or older, who are overweight, who have heart disease or high blood pressure, or who use medications that may be impacted by excessive heat are at a higher risk of heat stress [13-14].

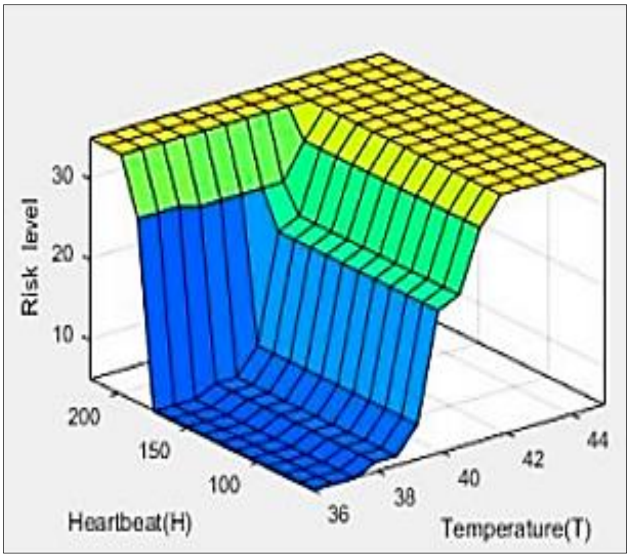


Fig 1 Heatstroke risk relationship with CBT and HR (Adopted from Son *et al.*) [1]

Heatstroke is a severe case of hyperthermia in which the body temperature is significantly increased. Heatstroke is a condition that happens because of excessive external temperatures or physical effort. Heat waves, extreme humidity, certain medications such as diuretics, beta-blockers, or alcohol, heart illness, and skin diseases are all risk factors [15, 16]. Heatstroke can occur in a matter of minutes. It is distinct from a fever, which is characterized by an elevation in the body's temperature set point. Heatstroke, alternatively referred to as sunstroke, is a type of severe heat-related illness that results in a body temperature greater than 40 °C and an increase in other physiological parameters such as heart rate and disorientation. The risk of heatstroke and how to influence HR and CBT is shown in (Fig 1). Additionally, dizziness, red skin, and headache may occur. Classic heatstroke is characterized by a lack of perspiration, whereas exertional heatstroke is characterized by excessive sweating [17, 20].

In another way, high temperatures can result in heat-related disease, which is a collection of illness disorders ranging in severity from moderate to severe (heatstroke). Heatstroke is traditionally described as a core temperature of greater than 40°C accompanied by CNS dysfunction. Generally, heatstroke can result in a death rate of up to 70%. A survival rate of up to 100% can be achieved if adequate treatment is initiated quickly [21-22].

Numerous new studies are aimed at enhancing the health-related quality of life of humans by developing and fabricating sensors that are either in direct touch with the human body (invasive) or indirectly in contact with the human body (non-invasive). Numerous wearable physiological monitoring devices have been created to protect people in sports, astronauts, soldiers, and firefighters suffering from heart-related illnesses. These systems are comprised of a variety of sensors that may be integrated into clothing/wearables to continually monitor the wearer's physical characteristics and health state [23]. The article of Garethiya et al. [24] in 2015 discuss GPRS and WiFi-based system that is primarily used to detect the presence of humans, particularly youngsters, inside locked cars. It determines the severity of heat illness by monitoring specific physiological markers [24]. Another wearable gadget based on Zigbee is presented in which a person's wrist and finger are worn (athlete or infant). The information is transmitted to the remote device via the low-energy wireless protocol Zigbee [25]. A smartwatch-based technology to detect heatstroke and water consumption based on body temperature was developed by Hamatani et al. [26]. A system for monitoring heat disorder in firefighters was proposed by Florea et al. [2013] that utilizes a wearable shirt equipped with sensors to measure temperature, humidity, and heart rate [27]. Similarly, a GPRS-based system was proposed by Mahdin et al. [28] to handle heatstroke, with the user movement detected by an accelerometer sensor. Similar techniques for treating heat exhaustion or heatstroke have been presented [28].

However, such a wearable and portable heatstroke alert device has not been created for the agricultural industry in India. Apart from that, when farmers work outdoors, they may overlook critical physiological warning signs and are frequently unaware that a heatstroke occurs.

Besides, the department of health predicted that by 2050, over 20 % of the world's population will be over the age of 65 [25]. So, farmers in their golden years are more susceptible to heatstroke. To avoid this deadly circumstance, there is a need to develop a wearable heat-stroke-detection device that will be capable of early alerting using specific physical sensors and environmental parameter monitoring sensors; if a risky condition is recognized, the gadget will trigger the alert function, reminding the user to take appropriate action to avoid farmers suffering from heatstroke. The device can transfer data to an Android phone using the HC-05 Bluetooth module from a greater distance. The developed device will warn farmers about the danger of heatstroke by considering all related sensory factors.

MATERIALS AND METHODS

The heatstroke alert system was developed to function effectively in hazardous environments and to monitor environmental and physiological data automatically in real time.

The architecture of the proposed device

Three independent phases of the study were required to develop WHSAS. The three unique processes consist of different interfacing components required for the construction of the WHSAS using Arduino Uno, constructing the necessary circuit for the device, and putting the components and circuits in an appropriate case with an armband seen in (Fig 2). The device comprises sensors, a computing unit, actuators, and a communication or data transfer unit. The sensor detected physical factors such as heart rate, body temperature, and environmental temperature and humidity, transmitting the data to the processing unit. This gadget employs the DHT11 temperature and humidity sensor, the DS18B20 body temperature sensor, and the pulse sensor. The processing unit analyses the data collected by the sensing unit and informs the actuating or alerting unit to take the necessary action. Arduino Uno is utilized as a processor. The alarm unit or actuator comprises red led, green led, and buzzer. Green led is illuminated while the working condition is normal, but red led, and a buzzer activates when the working condition exceeds the typical threshold. The communication unit transmits data and action status to the Android smartphone. The HC-05 Bluetooth module serves as a communication unit between Arduino and Android devices. The gadget is designed with significant heatstroke-affecting aspects in mind, such as physiological parameters (heart rate and core body temperature) and environmental characteristics (humidity and air temperature). The device's hardware and software were captivated by the following feature.

Fig 2 Development steps of wearable heatstroke alert system (WHSAS)

A. *Controlling and sensing elements*

1) *Microcontroller*

Arduino invented the Arduino Uno open-source microcontroller board [29]. It uses the Microchip ATmega328P microcontroller as its foundation. Digital and analog input/output (I/O) pins on the board allow it to communicate with a variety of expansion boards (shields) and other circuits. The board has fourteen digital I/O pins, six of which are PWM output-capable, and six analog I/O pins. It may be programmed using a USB A-to-B connector and the Arduino IDE (Integrated Development Environment) [30]. The board can be powered via a USB connection or an external 9-volt battery; however, it accepts voltages ranging from 7 to 20 volts. It is used to connect circuits between measuring sensors and a Bluetooth module for real-time monitoring of databases via the Bluetooth of an Android phone [31-33].

2) *Pulse sensor*

The TL-01251 pulse sensor is a plug-and-play sensor particularly intended for use with the Arduino platform. This sensor implements a straightforward optical pulse sensor, amplification, and noise reduction circuit. This circuit enables us to collect precise and quick readings of the heartbeat. This circuit operates at 4 mA and 5 V, making it excellent for mobile applications. This sensor functions by being connected to an Arduino board via a human fingertip or ear. Consequently, heart rate can be estimated [34].

3) *Body temperature sensor*

The body temperature sensor is generally used to detect the body temperature status of the human body. In this device DS18b20 temperature sensor (Temperature range: -55°C to +125°C, operating voltage: 3 V to 5 V, Output Resolution: 9-bit to 12-bit, Precision: 0.5°C, 12-bit conversion time: 750 ms) is used. It is generally attached to the armpit of the subject for two to three minutes. The sensor is impervious to water. The sensor readings can be obtained from either the armpit or the mouth [35].

4) *Ambient temperature and humidity sensor*

In this device, DHT11 is used for measuring environmental temperature and humidity. The DHT11 (Operating current: 0.3 mA, Resolution: Temperature and Humidity are both 16-bit, Humidity Range: 20% to 90%, Temperature Range: 0°C to 50°C, Accuracy: 1°C and 1%, Operating Voltage: 3.5 V to 5.5 V) is a simple, highly low-cost digital temperature and humidity sensor. It measures the ambient air using a capacitive humidity sensor and a thermistor and outputs a digital signal on the data pin (no analog input pins needed). It's straightforward to use, but data collection requires some finesse [36].

5) *Communication unit*

Wireless sensing units combine wireless communications, mobile computers, and transducers to produce a low-cost sensor platform suited for a variety of applications. In the event of an emergency, the uninterrupted flow of sensed data requires long-range wireless connectivity. With Bluetooth, data collecting, analysis, and processing have become more convenient and transparent.

The HC-05 Bluetooth module is utilized to transmit data to Android devices. The HC-05 module is a Bluetooth serial communication module that is commonly employed in electronic projects. Bluetooth module HC-05 required specifications: 3.6 V to 5 V operational voltage and 30 mA operating current. The HC-05 Bluetooth module communicates with a smartphone via a Bluetooth Arduino app. The Bluetooth range for the HC-05 module is around 10 meters, which is sufficient for the majority of devices, has low power consumption, and is simple to connect.

6) *Alert units*

Above all hardware components, a 50-14000 Hz frequency buzzer and green and red led light to fascinate the alert system is used. When physiological and meteorological parameters cross the threshold value, the system warns by activating the alert system, and the farmers may stop the work and rest in the shadow area.

Table 1 The major components of the Wearable Heatstroke Alert System (WHSAS)

Components	The quantity used (numbers)
Arduino Uno	1
USB cable	1
Android	1
HC-05 App	1
Bluetooth module (HC-05)	1
DHT11	1
DS18b20 temperature sensor	1
Pulse sensor	1
Veroboard	1
Buzzer	1
LED (Red and Green)	2
Resistor (470Ω and 220Ω)	6
Wires (Jumper)	18
Arduino cable (USB A-B)	1
Power Bank (10000 mAh)	1
Male and female header	2
Transparent box	1
Velcro belt	1

B. *Circuit diagram and development of WHSAS*

The WHSAS circuit diagram is depicted in (Fig 3). The components are listed in (Table 1). Following the circuit diagram, all components are soldered to a Veroboard and connected or installed there. The engineered system is encased in a clear plastic box (6 cm × 15 cm). The plastic container features straps for mounting the package on the upper arm during fieldwork. The required algorithms for the WHSAS illustrates in (Fig 4). The algorithm is written in C language in Arduino IDE and uploaded via USB cable to Arduino Uno. A Bluetooth app for Android is used to monitor and collect physiological and climatic data and the alert system.

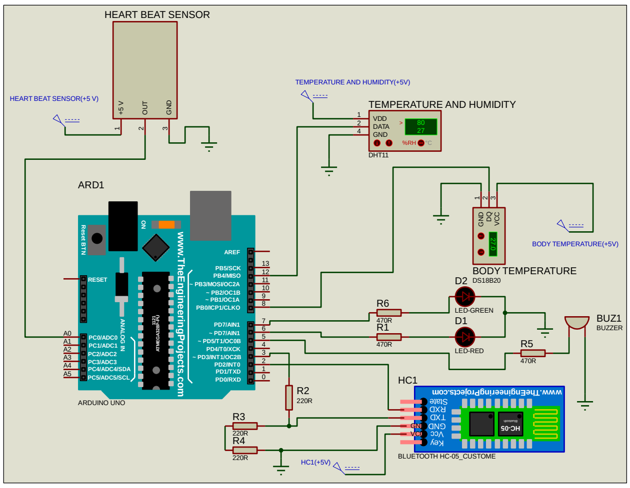


Fig 3 Circuit diagram and components of wearable heatstroke alert system

The device monitors the heart rate (bpm), core body temperature (CBT) (°C), surrounding temperature (°C), and humidity continually (%). As is well-known, heatstroke is a disease of the advanced level of heat and typically occurs when the core body temperature (CBT) rises above 40°C, and the heart rate exceeds 75% of the maximal heart rate in extreme heat stress settings. Based on the premise, employed the optimal threshold limit in the coding such that the WHSAS would trigger an alert before the onset of heatstroke. The maximum HR was calculated using Roberg's and Landwehr's formula (HR_{max} = 205.8 - 0.685 × age) [37]. The threshold values have been established for pulse rate or heart rate of 130 bpm, CBT temperature of 37°C, and environmental temperature and humidity of 33°C and 70%, respectively. The alarm system was initiated by the control system when a parameter exceeded its threshold value. The wearable wristband allows gadget mobility. Due to this feature, farmers can carry it in their arms while working.

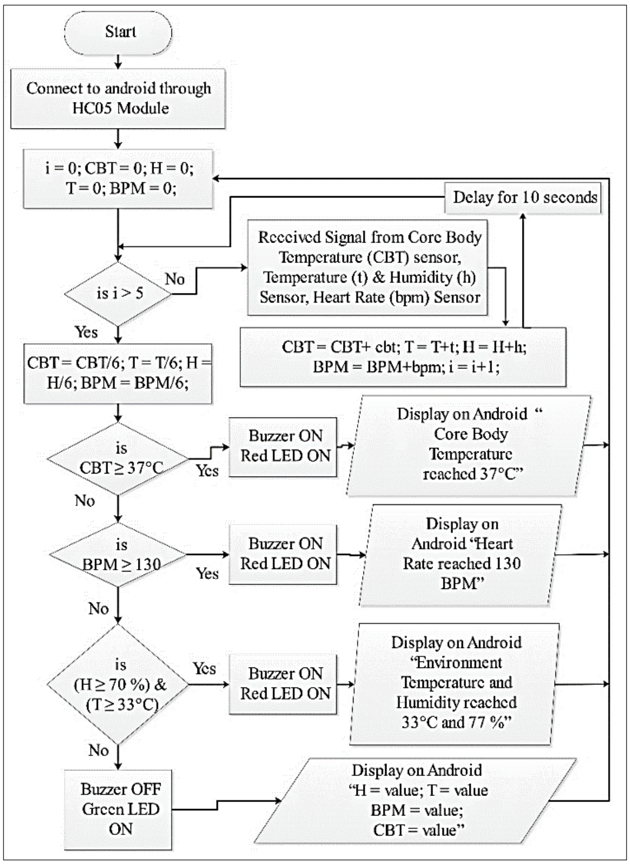


Fig 4 Flowchart of the algorithm of wearable heatstroke alarming system

Field assessment of prototype WHSAS

After developing a WHSAS prototype and an examination was carried out in an agricultural setting. The experiment was conducted in the experimental field of the Agricultural Engineering Department at NERIST, Nirjuli-791109, Arunachal Pradesh. Two agricultural laborers were chosen to participate in the experiment. Before the ergonomic test, the volunteers were instructed on how to use the equipment. Both subjects' anthropometric measures were taken. The average age (years), height, maximal heart rate, weight (kg), BSA, and BMI are 28 years, 162 cm, 186 bpm, 56 kg, 1.68 m^2, and 21.5 kg/m^2, respectively.

Before evaluating the dynamic work performance, static performance was calibrated using a Polar HR monitor (Polar M200, working temperatures 0 °C to 50 °C, GPS capability), a digital thermometer (Accuracy: normally in 1 minute with 0.1 °C, Range: 32 °C to 42.9 °C), and a digital thermo hygrometer (Temperature Range: -50 °C to 70 °C, Humidity Range: 10 % RH to 99 % RH, Resolution: Temp. 0.1°C, Humidity: 1 % RH).

The acquired information was compared to measurements obtained from commercial instruments. The average error and mean absolute percentage error were derived through this comparison. Before the gadget alerted us, dynamic work performance was examined while making raised beds with a spade in hot and humid conditions, a heavy category of agricultural work.

RESULTS AND DISCUSSION

To combat the risk of heatstroke among farmers, a wearable heatstroke detecting system was used. The gadget was meant to provide early warning of heatstroke to individuals who work in hazardous situations, are ill, or are elderly.

By correctly wearing the gadget, it detects physiological and environmental data instantly and automatically. The pulse sensor is attached to the ear with an ear clip, whereas the CBT measurement sensor is placed in the mouth or armpit. The system was secured to the user's arm using Velcro, and the DHT11 sensor was exposed to the environment via a suitable attachment. The device is powered by an Android smartphone or power bank through a USB cable connection. After all the sensors have been connected and the device is powered on, the device will activate, as indicated by the illumination of green led. When biosensors collect data, it is delivered wirelessly through Bluetooth to a smartphone for processing and analysis. The key advantage of the device is its portability, and data may be delivered to an Android phone via Bluetooth connection even without an internet connection. Due to the absence of an internet connection requirement, it is perfect for rural locations. The created device detects physiological and meteorological factors continually. This environmental and physiological information is then utilized to determine the likelihood of heatstroke. When physiological and meteorological parameters exceed the threshold limits, the developed device gives alarms via a buzzer, a red led, and a message sent via the HC-05 android application. The device's low cost will facilitate its adoption by small and marginal farmers.

As most farmers are illiterate and uninformed of their physiological state while working in intense heat, this equipment will assist them in becoming aware of any potential dangers that may develop while working in such conditions. When farmers continuously work outdoors, their physiological parameters gradually alter. This shift will be more pronounced when the farmer is significantly older, poorly acclimated, in poor physical shape, and has undergone considerable amounts of heat stress. In such conditions, heat disorders are prevalent among farmers. When farmers work in hot weather while wearing WHSAS, the sensor continuously analyzes their physiological data. It communicates it to an Android phone via the Bluetooth module (HC-05) on a secondary basis. When the user's heart rate reaches 130 beats per minute (bpm), the user's core body temperature (CBT) surpasses 37 °C, or the ambient temperature and humidity exceed 33 °C and 80 %, respectively, the device alerts the user with a blinking red led or a beeping buzzer. These characteristics can be modified using coding based on needs and environmental conditions. After being notified, farmers are instructed to rest in a shady spot while taking electrolytes to aid with their speedy physical recovery.

Performance evaluation of WHSAS

To determine the heatstroke warning within a short period, choose a sunny, hot day with strenuous agricultural labor. The device was evaluated under two distinct situations. One is at rest, while the other is in functioning condition. The WHSAS was calibrated while the subject was at rest, and the subject's alert status was evaluated on the field.

Resting conditions

During the farmer's resting state, all physiological markers are nearly steady. With the aid of the Bluetooth module, the microcontroller transmits data continually to the Android HC-05 application. According to the findings, all sensors can measure physiological and climatic factors without considerable variation. In addition, the physiological and climatic parameters of WHSAS are compared to those of Commercial Equipment (CE) (Table 2). The testing procedure measured physiological and climatic characteristics using a polar heart rate monitor (M200), a digital thermometer, a digital Thermo hygrometer and a WBGT meter.

Observations revealed that the sensor collected data identically to commercial equipment, with no discernible difference. This investigation revealed that the average difference between commercial equipment measurements and those conducted with the device developed in this study was minimal.

Table 2 Comparison of the physiological and meteorological data of WHSAS with Commercial Equipment (CE) data

Time (min)	HR by WHSAS (bpm)	HR by CE	Error	CBT by WHSAS	CBT by CE	Error	ET by WHSAS	ET by CE	Error	EH by WHSAS	EH by CE	Error
1	75	78	-3	36.49	36.56	0.07	38	38	0	42	42	0
2	81	80	1	36.53	36.55	0.02	38	38	0	42	42	0
3	77	79	-2	36.55	36.56	0.01	38	38	0	42	42	0
4	84	81	3	36.54	36.56	0.02	38	38	0	42	42	0
5	81	80	1	36.56	36.56	0	38	38	0	42	42	0
6	81	80	1	36.56	36.56	0	38	38	0	43	42	1
7	87	86	1	36.58	36.56	0.02	38	38	0	42	42	0
8	84	80	4	36.58	36.56	0.02	38	38	0	42	40	2
9	89	87	2	36.6	36.58	0.02	37	38	-1	42	42	0
10	85	84	1	36.63	36.58	0.05	38	38	0	42	42	0
11	81	83	-2	36.59	36.58	0.01	38	38.5	-0.5	42	42	0
12	79	82	-3	36.58	36.58	0	38	38	0	42	42	0
13	81	80	1	36.57	36.58	0.01	39	38	1	42	42	0
14	84	84	0	36.61	36.59	0.02	38	38	0	40	42	-2
15	82	85	-3	36.6	36.59	0.01	39	38	1	42	42	0
Mean Error		0.13			0.0012			0.033			0.058	

In the instance of WHSAS recorded HR, it fluctuates between 75 and 87 bpm for 15 minutes, whereas the same measure by M200 ranges between 78 and 86 bpm with an average deviation of 0.13 under resting conditions. In the same conditions, CBT is also assessed in terms of oral temperature. CBT was found to vary between 36.49 to 36.59°C by WHSAS and from 36.56 to 36.59°C by a digital thermometer, with a standard deviation of 0.0012. In addition, the variance in environmental temperature and humidity was evaluated. Environmental Temperature (ET) and Environmental Humidity (EH) were observed to vary from 37 to 39°C and 40 to 43 % for WHSAS and from 38 to 38.5°C and 40 to 42% for digital thermo hygrometer, with average deviations of 0.033°C and 0.058% respectively.

Working condition

The field evaluation test of WHSAS was carried out for working conditions. Two separate tests (Test 1 and Test 2) were carried out with the help of farmers during making raised beds by spade (Fig 5).

Fig 5 Field evaluation of WHSAS during making raised beds by spade

During the operation of raised beds with a spade, the WHSAS continuously monitors physiological and environmental responses. It depicts the performance of the WHSAS for several individual parameters graphically (Fig 5-9). The device's alert signal also provides a graphical representation of its duration (Fig 7). Farmers should relax in shady areas and consume cool electrolyte water to restore their physiological circumstances if the gadget alerts them to the risk of heatstroke in the surrounding environment. The device will only provide an alarm when physiological and climatic factors exceed a predetermined threshold. During field operations, the first subject's heart rate and CBT vary from 82 to 116 bpm and 36.53 to 37.01°C, respectively, for the first subject, and 79 to 115 bpm and 36.48 to 37.03°C, respectively, for the second subject. Temperature and humidity range from 37 to 39°C and 40 to 43%, respectively, for Test 1 during experimental field conditions and from 38 to 39°C and 40 to 43% for Test 2 during experimental field conditions.

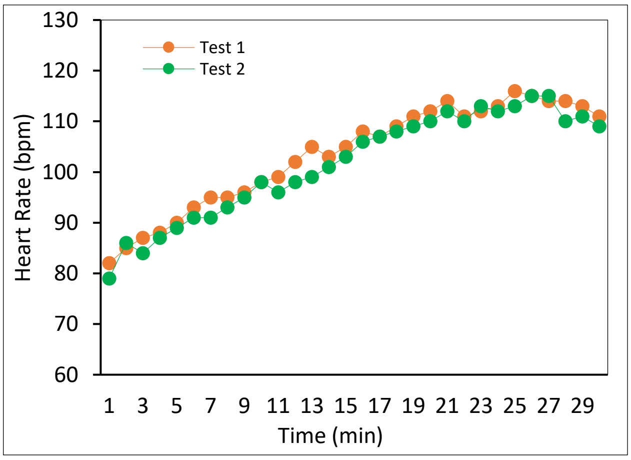


Fig 6 Status of heart rate of farmers for Test 1 and Test 2 during field operation measured by WHSAS

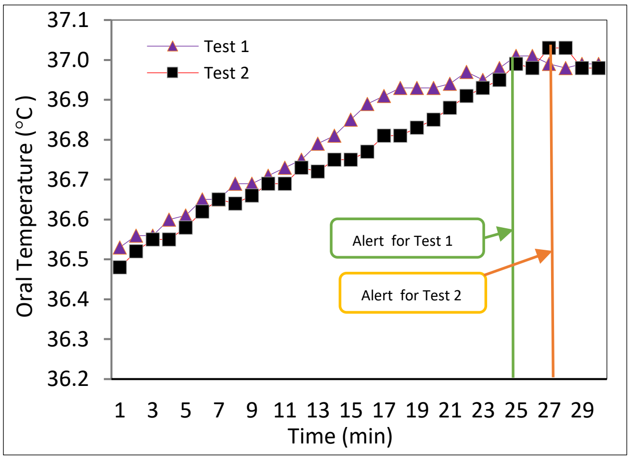
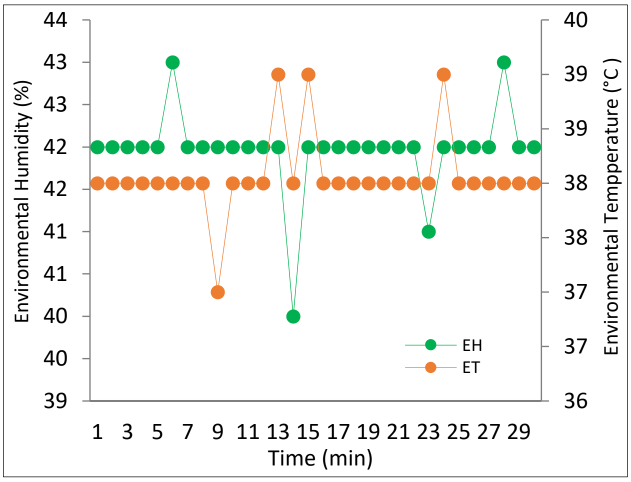


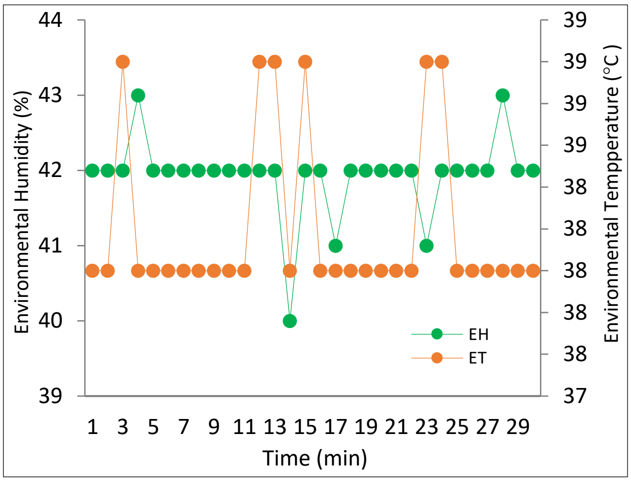
Fig 7 Status of the oral temperature of farmers with the status of alert for Test 1 & Test 2 during field operation measured by WHSAS

The device sends a warning for the first test at 25 minutes and the second test at 27 minutes due to exceeding the CBT threshold limit (37°C) (Fig 7). HR and climatic parameters did not generate an alarm because they did not surpass the threshold level. Due to the varying physical circumstances of the selected farmers, it has been observed varying physiological characteristics.

Consequently, heatstroke can be avoided by implementing the WHSAS system. The device functions without interruption while held in one arm by a farmer, but there is a potential that it will malfunction if placed in a bag or pocket. Using this device, the user can determine the physiological and environmental status of their body and its location. In addition, the device is incredibly inexpensive, making it affordable for marginal and small farmers. Due to the low cost and simplicity of the equipment, farmers can utilize it in the field. In addition to measuring physiological and environmental indicators, this gadget can also be used to measure other circumstances.

As previously stated, heatstroke typically happens when core body temperature (CBT) rises well above 40 degrees Celsius. In addition, it was discovered that the majority of the experimental areas of our research exhibit 32°C WBGT, which, according to ACGIH recommendations, indicates heat stress. To avoid the risk, the device was designed to inform the farmer when the farmer's physiological response exceeds the previously mentioned threshold and well before heatstroke. Considering the issue, two farmers were recruited for the afternoon (about noon) spreading to evaluate the gadget's effectiveness. It was shown that extreme heat and arduous agricultural labor significantly impact farmers' CBT and cause it to exceed 37°C. The increase in CBT of more than 0.50°C every 30 minutes of work is indicative of the risk of heat illness. Additional effort under the same conditions may result in heatstroke. So, to prevent farmers from working after receiving the notice. Further, it has been observed that the developed heatstroke alert system is capable of alerting farmers when physiological and climatic indicators rise abruptly before the onset of heatstroke.





ET- Environmental Temperature °C, EH-Environmental Humidity (%)

Fig 8 Status of ET and EH during field operation measured by WHSAS for Test 1

Fig 9 Status of ET and EH during field operation measured by WHSAS for Test 2

CONCLUSION

The developed Wearable Heatstroke Alert System (WHSAS) working based on physiological and environmental parameters was tested and validated in the field condition. The developed system is economical and user-friendly. It would be very useful for the farmers to prevent any unwelcome heat disorders while working in outdoor conditions. It measures physiological and climatic data in open fields when farmers are exposed to high temperatures and high humidity. The system gives an alert and warning if the threshold limit of physiological and environmental parameters exceeds the values. It can be operated without internet connectivity in rural areas where the availability of internet is very rare. The usage of WHSAS can assist to reduce the risk of heatstroke in the agriculture sector under field conditions. Further, this gadget also assesses the intensity of fieldwork in terms of heart rate and environmental conditions.

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