Evolution in Electrical and Electronic Engineering Vol. 4 No. 2 (2023) 740-749


EEEE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/eeee
e-ISSN : 2756-8458

# Early Heatstroke Risk Detection for Children with IoT Technology

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DOI: https://doi.org/10.30880/eeee.2023.04.02.089
Received 10 July 2023; Accepted 10 September 2023; Available online 30 October 2023

**Abstract**: Heatstroke is a medical emergency that may cause brain damage and other internal organ failure. It is caused by overheating, which usually occurs when a person lacks sweating while doing activities or is exposed for a long period to high surrounding temperatures with low humidity. This device measure and monitor the body temperature, sweating rate, heart rate, oxygen saturation (SpO2), the surrounding temperature, and humidity, as a result, heat stroke level risk will be generated through the Durian UNO with ESP8266 microcontroller and notify the User through Blynk application as for the IoT part. Based on the result, it can be concluded that the device is capable of detecting heat stroke risk and alerting the user before any heat stroke occurrence. The device can detect heat stroke risk with an accuracy ranging from 98.46% to 99.87%, providing early alerts to prevent heat stroke occurrences.

**Keywords**: Heatstroke, IoT Technology, Children

## 1. Introduction

In Malaysia, heat waves can be identified as a yearly phenomenon where Malaysia's climate is Tropical Wet and the highest recorded temperature was 33 degrees Celsius in May with high relative humidity from 65% to 90% [1]. However, this experience should not be taken lightly as it can cause serious health problems. Exposure to high temperature for a long period can cause fatal and leads to heatstroke. Extreme hot weather can cause excessive sweating and reduction of fluids in one's body which in turn, can lead to tiredness, lethargy, and muscle cramps [2]. If the condition is left untreated, it may cause the body to dehydrate and can damage the body's important organs such as the heart, liver, kidneys, and brain. Even though Malaysia has the fewest cases of heat stroke among children, the tropical temperature and high humidity may lead to heat-related medical problems, especially among children with medical conditions.

Based on the research that has been made, there are various existing works related to heatstroke that have been developed, however, not all were applicable to children. Most of the research were focused on adult usage and were not suitable to be applied for children due to different relative

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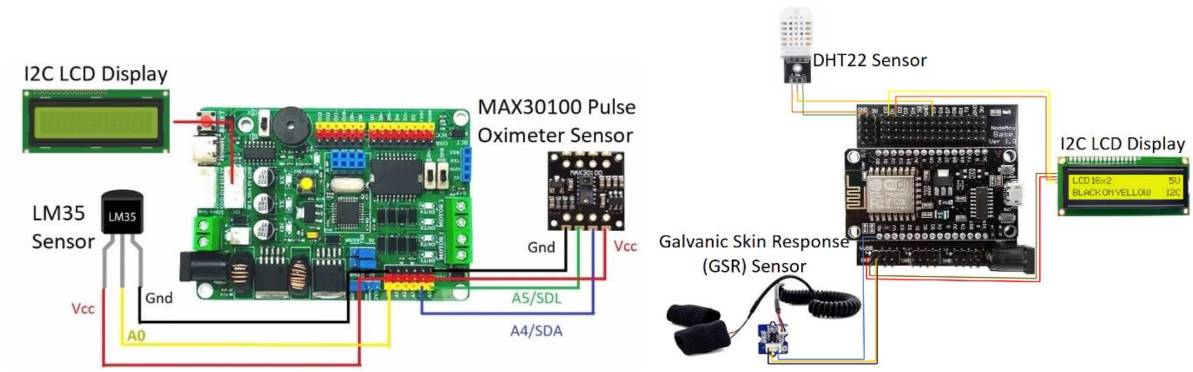
parameters that will be measured. Furthermore, the risk of children getting exposed to heatstroke is higher than the adults due to the capability of regulating their body temperature [3]. With the world facing global-scaled environmental damage, weather can be unpredictable and heat waves may occur. In addition, for children's development, it is normal for them to continue playing despite being worried about the weather or getting sick while playing. Thus, they might not be familiar with medical problems related to heat exposure. Lastly, parents or guardians were incapable of monitoring their children while they were at school, on the field, or anywhere outside.

This work should be able to measure and monitor body temperature, sweating rate, heart rate, oxygen saturation, surrounding temperature, and humidity. This work utilized the Blynk application by embedding the microcontroller as an IoT communication tool to transfer data in a user-friendly interface to parents or guardians and send alerts by pop-up notification. This work is tailor-made to suit the needs of children under 12 years old design-wise.

## 2. Materials and Methods

This work utilized two microcontrollers: the Durian Uno microcontroller and the NodeMCU ESP8266. The Durian Uno microcontrollers as in Figure 1(a) connected with the LM35 for body temperature measurement and MAX30100 for heart rate and saturated oxygen (SpO2) level measurement. The temperature measurement should not exceed 38°C which will be considered as fever, meanwhile, the heart rate should not exceed 130 bpm, or else will trigger a warning level. The Durian Uno microcontroller has a built-in buzzer, thus, by employing the feature, any detected abnormal measurement will trigger the buzzer. The children with the device and the parent will be notified through the buzzer and smartphone with Blynk software.




(a) (b)

**Figure 1: System circuit diagram using a) Durian Uno microcontroller and b) NodeMCU ESP8266**

The NodeMCU ESP8266 as in Figure 1 (b) connected with the Galvanic Skin Response (GSR) sensor for sweat rate measurement and DHT22 for the surrounding temperature and humidity measurement. However, the GSR sensor and the DHT22 has no function of triggering the buzzer and sending data alert. Yet, both microcontrollers will send data to Blynk for real-time monitoring and display the measurement at both the Blynk interface and LCD displays. Whenever the microcontrollers have an internet connection, the measurement will be taken continuously, and the data will be recorded in Blynk. The reset function indicates the off button (no power supply) and the system will start again from the beginning. Figure 2 shows the system flowchart starting from initializing the internet connection for both microcontrollers to measure the required parameters. If there were no abnormal readings and available power supply, both microcontrollers will continuously record measurements and displays in both LCD displays and the Blynk application.

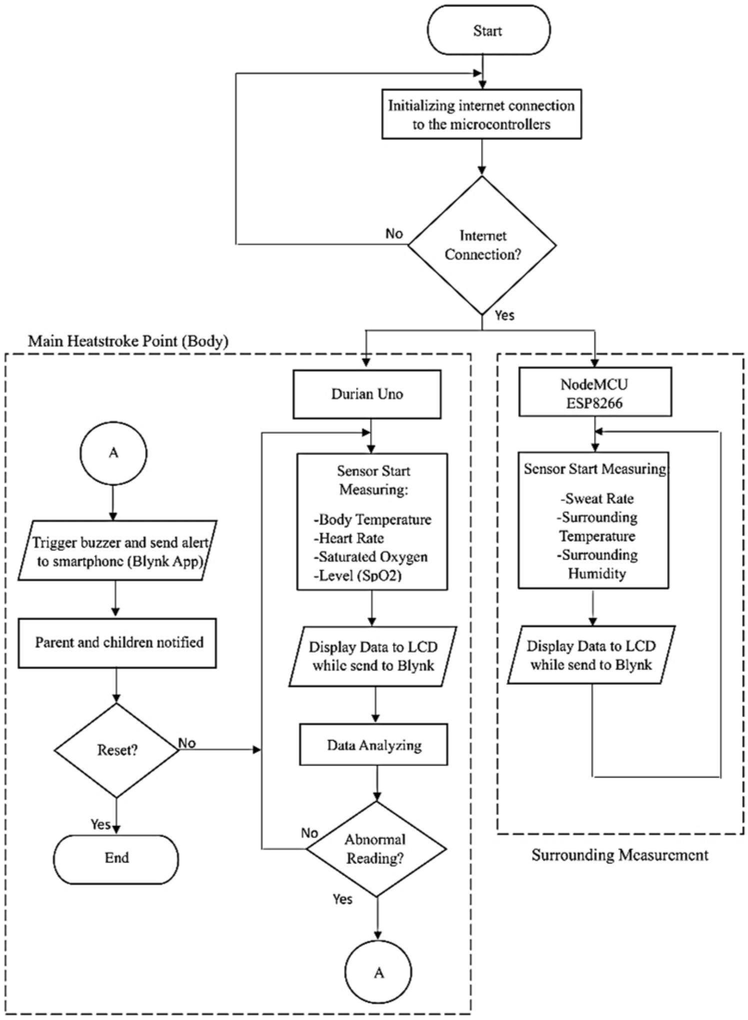



**Figure 2: System Flowchart**

The Durian Uno microcontroller plays a pivotal role as it has the core components that measure the main physiological factors for heatstroke risk level which are the body temperature, heart rate, and saturated oxygen (SpO2) level, and advanced capabilities in monitoring those vital signs. A validity test for both LM35 and MAX30100 was carried out to ensure the connected sensors record accurate measurements. The LM35 measurement was compared with the Thermometer BSX916 meanwhile the MAX30100 was compared with the RoHS LK-87 Fingertip Pulse Oximeter Equations. The relative errors (Eq.1), mean relative errors (Eq.2) and mean accuracy (Eq.3) for the recorded measurement were calculated by using three equations. The result shows the LM35 has an accuracy of 99.87% and the MAX3000 shows an accuracy of 98.46% for heart rate and 99.5% for saturated oxygen (SpO2) level. A detailed validity result for both tests can be referred to Table 1 in Point 3.1, the result and discussion.

$$Relative\ Error = \frac{|Measured\ Value - Actual\ Value|}{Actual\ Value}\ x\ 100\% \qquad Eq.1$$

$$Mean\ Error = \frac{Total\ Relative\ Error\ (\%)}{Total\ Reading} \qquad Eq.2$$

$$Mean\ Accuracy = 100\% - \ Mean\ Error \qquad Eq.3$$

## 3. Results and Discussion

The system validity test was carried out with 10 times measurements for LM35 and MAX30100 with available commercial devices. This comprehensive approach guarantees a complete evaluation of heatstroke risk, enabling individuals to proactively address and reduce potential risks. The MAX30100 measures the saturated oxygen (SpO2) level and heart rate, thus the results were compared to the RoHS LK-87 Fingertip Pulse Oximeter, meanwhile, for LM35 which measures the body temperature was compared with the Thermometer BSX916 to ensure the measurement was valid. Upon conducting the calculation and analysis of the MAX30100 comparison data, the results show a low error rate of 1.54% for heart rate measurements and a mere 0.5% for SpO2 level measurements. Furthermore, most SpO2 level readings show an error rate of 0%, highlighting exceptional precision. Moreover, the heart rate measurements demonstrate errors of less than 3%, further attesting to the reliability of the MAX30100 device. By determining the mean error through comprehensive calculations, it becomes evident that the accuracy of the MAX30100 reaches 98.46% for heart rate measurements and 99.5% for SpO2 level measurements. These findings allow for confident identification and conclusive affirmation of the MAX30100's reliability and effectiveness in accurately assessing both heart rate and SpO2 levels. Meanwhile, for LM35, the measurement result shows that the mean relative error of LM35 from the thermometer is 0.132%, with a total of 1.32% relative error. By calculating the mean error, the result shows that the accuracy of the thermometer, when compared against measurements obtained from a commercially available device, stands at an impressive 99.87% for body temperature measurements. These findings show identification and affirmation of the LM35's reliability and effectiveness in accurately assessing the body temperature readings.

After evaluating the accuracies of both sensors, the work continued by collecting various data points from the children. This included body temperature, heart rate, saturated oxygen (SpO2) level, sweat rate, surrounding temperature, and humidity. The data collection took place at two different locations: the residential area at Taman Kurnia Jaya and the open hall of Sekolah Kebangsaan Dato' Hashim 2 in the morning. Regardless of the location, all participating children were required to engage in the same activities specifically walking, running, and jumping. During the walking activity, the children will be required to cover a distance of 10 meters within a time limit of 20 seconds. Similarly, for the running activity, they will need to complete a 10-meter run within a timeframe of 20 seconds. During the jumping activity, the children will be instructed to perform 20 Jumping Jacks within a time frame of 20 seconds. A carefully selected group of 12 healthy children, ranging from 7 to 12 years old, has been chosen to participate in the test. The testing environment was controlled to ensure the safety and well-being of the participants. These standardized methods were employed to maintain consistency and minimize result variations, thus upholding the reliability and validity of the measurement process.

### 3.1 Residential Area Measurement Result

Table 1 shows the surrounding temperature and humidity in the residential area at Taman Kurnia Jaya, Kota Bharu, Kelantan. In the first measurement and subsequent readings, the time intervals were selected to cover specific periods such as morning, noon, and evening. These time slots were chosen to capture variations in environmental conditions throughout the day and provide a comprehensive understanding of the factors influencing the measurements. The temperature and humidity readings from Kota Bharu Weather Station were also included in Table 1 as a reference.

Table 2 shows the measurements of heart rate, sweat rate, body temperature, and saturated oxygen (SpO2) level that were obtained at their residential area in the morning. The first measurement (Before Activities) was recorded after the children had taken their breakfast at 8:00 a.m. before they began the required activities. The heart rate has already shown elevated readings even though no activities have been done yet. The children's body temperature was at its lowest, considering the time when the measurement was taken. The body temperature, heart rate, and sweat rate show increment after doing the activities, however, the SpO2 level insignificantly drops and re-elevates.

**Table 1: Temperature and Humidity in Residential Area**

| Time | Residential Area | | Weather Station | |
|---|---|---|---|---|
| | Temp | Hum | Temp | Hum |
| 7:40 am | 27.30°C | 93% | 27.00°C | 94% |
| 8.20 am | 28.50°C | 91% | 28.00°C | 91% |
| 9.00 am | 29.10°C | 89% | 29.00°C | 84% |
| 10.00 am | 31.00°C | 75% | 31.00°C | 79% |
| 11.00 pm | 32.15°C | 71% | 32.00°C | 75% |
| 12.00 pm | 32.30°C | 72% | 33.00°C | 71% |
| 5:30 pm | 32.17°C | 71% | 32.00°C | 75% |
| 6:00 pm | 31.17°C | 73% | 31.00°C | 75% |

*Temp = Temperature, Hum= Humidity

**Table 2: Morning Measurement**

| Age | Body Temp | Heart Rate | SpO2 | Sweat Rate |
|---|---|---|---|---|
| | **Before Activities** | | | |
| 7-8 years old | 35.64°C | 94 | 99% | 8% |
| 9-10 years old | 35.64°C | 89 | 99% | 8% |
| 11-12 years old | 35.64°C | 84 | 98% | 8% |
| | **Walking** | | | |
| 7-8 years old | 36.62°C | 108 | 99% | 10% |
| 9-10 years old | 36.13°C | 98 | 98% | 12% |
| 11-12 years old | 36.13°C | 93 | 95% | 11% |
| | **Running** | | | |
| 7-8 years old | 36.62°C | 120 | 98% | 12% |
| 9-10 years old | 36.62°C | 108 | 98% | 14% |
| 11-12 years old | 36.13°C | 116 | 99% | 14% |
| | **Jumping** | | | |
| 7-8 years old | 37.11°C | 162 | 97% | 12% |
| 9-10 years old | 37.11°C | 141 | 98% | 14% |
| 11-12 years old | 36.62°C | 120 | 98% | 16% |

*Temp= Temperature, SpO2= Saturated Oxygen Level

**Table 3: Evening Measurement**

| Age | Body Temp | Heart Rate | SpO2 | Sweat Rate |
|---|---|---|---|---|
| | **Before Activities** | | | |
| 7-8 years old | 36.62°C | 94 | 99% | 8% |
| 9-10 years old | 36.62°C | 76 | 99% | 9% |
| 11-12 years old | 36.13°C | 73 | 98% | 8% |
| | **Walking** | | | |
| 7-8 years old | 36.62°C | 120 | 99% | 10% |
| 9-10 years old | 36.62°C | 94 | 98% | 10% |
| 11-12 years old | 36.13°C | 93 | 95% | 12% |
| | **Running** | | | |
| 7-8 years old | 37.11°C | 141 | 98% | 10% |
| 9-10 years old | 36.62°C | 108 | 98% | 12% |
| 11-12 years old | 36.13°C | 111 | 99% | 14% |
| | **Jumping** | | | |
| 7-8 years old | 37.11°C | 162 | 97% | 12% |
| 9-10 years old | 37.11°C | 141 | 98% | 14% |
| 11-12 years old | 36.62°C | 120 | 98% | 16% |

*Temp= Temperature, SpO2= Saturated Oxygen Level

Table 3 shows the measurements of heart rate, sweat rate, body temperature, and saturated oxygen (SpO2) level that were obtained at their residential area in the evening. The first measurement (Before Activities) was recorded at 6:00 p.m. as the surrounding temperature and the humidity at the lowest point of the day for the evening. The heart rate has already shown elevated readings even though no activities have been done yet. The children's body temperatures were slightly higher than in the morning, considering the time when the measurement was taken. The body temperature, heart rate, and sweat rate show increment after doing the activities, however, the SpO2 level insignificantly drops and re-elevates, same as the measurement in the morning.

Figure 3 shows the graph of heart rate measurement during the test carried out in the morning, which generally remains elevated compared to before conducting the test measurements. It shows that children of 7 to 8 years old have the highest heart rate recorded before any activities after the activities test have been carried out. This clearly shows that smaller children tend to have higher heart rates than bigger children. Figure 4 shows that their body temperature increased after doing the activities, however, their sweat rate was less than that children of 9 to 10 years old and 11 to 12 years old as in Figure 5. Figure 4 also shows that the children of 11-12 years old have the lowest body temperature measurement before and after the test activity has been carried out. Figure 5 shows the sweat rate before activities is the same for all age groups, indicating similar baseline perspiration levels. After the test has been carried out, the sweat rate shows slight variations but remains relatively consistent across age groups. The children of 11 to 12 years old sweating rate actively increases with every activity, hence, they are able to regulate their body temperature more and resulting in lower body temperature compared to other children as in Figure 4.

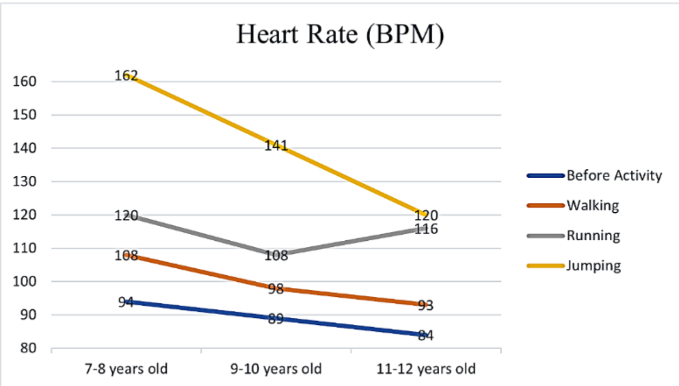



**Figure 3: Morning heart rate (BPM)**

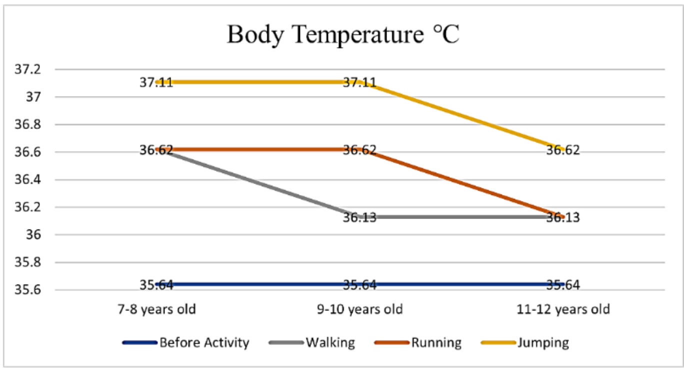



**Figure 4: Morning body temperature (°C)**

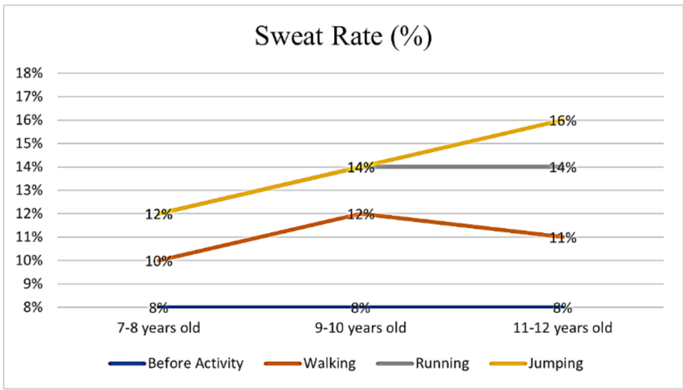



**Figure 5: Morning sweat rate (%)**

Figure 6 shows the graph of heart rate measurement, Figure 7 shows the graph for body temperature measurement and Figure 8 shows the sweating rate measurement during the test carried out in the evening. For body temperature measurements that were recorded in Figure 6 show that the average body temperature remains relatively consistent across all age groups and activities, with slight variations observed in some cases. Meanwhile, Figure 7 shows the heart rate measurement increases during physical activities compared to before activities. Children of 7 to 8 years old show the highest heart rate among the two other age groups and have the most significant escalation. There is a consistent increase in heart rate during walking and running activities. Figure 8 shows the measurement result for sweating rate had constantly increased during activities. 11 to 12 years old children have the highest sweating rate compared to other children before and after doing the test activities. To conclude, they are able to regulate their body temperature more than children 7-8 years old by sweating as in Figure 7.

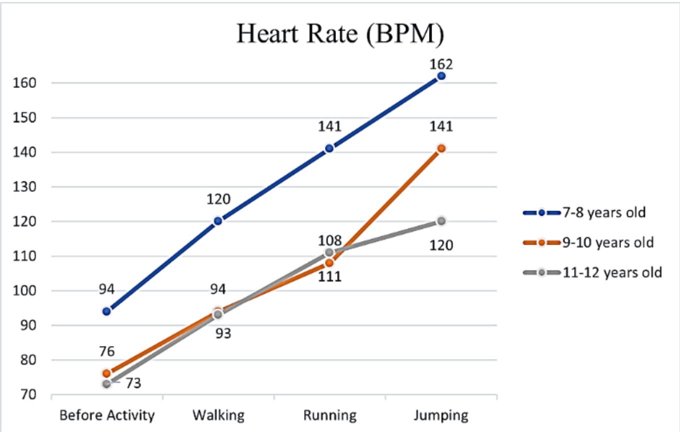



**Figure 6: Evening heart rate (BPM)**

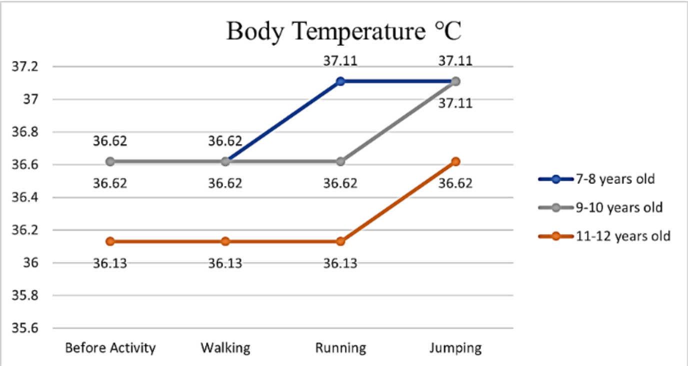



**Figure 7: Evening body temperature (°C)**

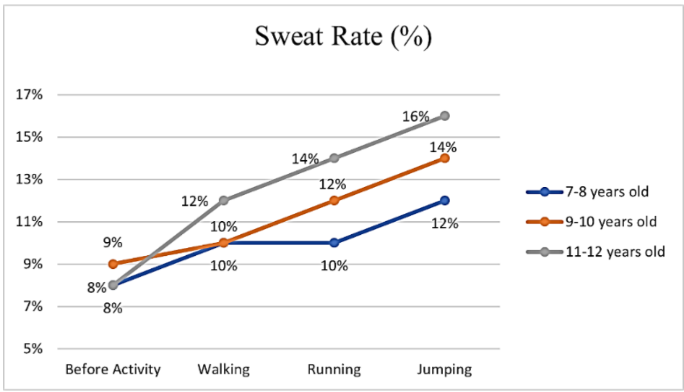



**Figure 8: Evening sweat rate (%)**

3.2 School Open Hall Measurement Result

Table 4 shows the surrounding temperature and humidity at the school hall and school field. The temperature and humidity readings from Kota Bharu Weather Station [4][5] were also included in Table 4 as a reference.

The temperature readings show an increasing trend throughout the day across all locations. In the morning, from 07:40 am to 08:20 am, the temperatures range from 27.30℃ to 28.20℃. As the temperatures continue to rise, the highest recorded temperatures range from 31.00℃ to 34.00℃. This suggests a gradual increase in ambient temperature as the day advances. As for the humidity, the levels show some variations however remain within a relatively high range. The highest humidity level was at 07:40 am to 08:20 am, from 92% to 98%. As the day progresses, the humidity levels decrease slightly, ranging from 82% to 91% during midday and afternoon hours. The lowest humidity reading is recorded in the afternoon at 75%. Overall, the data indicates a moderately humid environment throughout the day. When comparing the temperature and humidity readings among the three locations, the Weather Station consistently records slightly higher temperatures compared to the School Open Hall and School Field. Similarly, the humidity levels at the Weather Station also tend to be higher than those in the other locations. These differences could be attributed to the specific microclimatic conditions and the positioning of the Weather Station in a different area.

**Table 4: Temperature and Humidity in School Area**

| Time | School Open Hall | | School Field | | Weather Station | |
|---|---|---|---|---|---|---|
| | Temp | Hum | Temp | Hum | Temp | Hum |
| 07:40 am – 08.20 am | 27.30℃ | 93% | 27.60℃ | 92% | 28.20℃ | 98% |
| 09.00 am – 10.00 am | 28.50℃ | 91% | 30.40℃ | 90% | 30.40℃ | 91% |
| 11.00 am – 12.00 am | 29.10℃ | 89% | 33.70℃ | 82% | 33.60℃ | 82% |
| 01.00 pm – 02.00 pm | 31.00℃ | 75% | 34.00℃ | 79% | 33.00℃ | 83% |
| 05.30 pm – 06.30 pm | 32.00℃ | 71% | 33.00℃ | 74% | 32.10℃ | 72% |

Table 5 shows the heart rate (BPM), body temperature, sweat rate, and saturated oxygen (SpO2) level of the participating children before (resting) and Table 6 shows the measurement result after doing the activities at the school hall in the morning. Table 6 shows a noticeable increase in body temperature compared to the previous measurements in Table 5. The average body temperature now ranges from 36.45℃ to 37.30℃, with the highest recorded for the 7-year-old group. Furthermore, the heart rates have also shown an upward trend in this set of measurements from 109 to 130 beats per minute, indicating an elevated cardiovascular response during physical activity, and the highest heart rate is recorded for the 7-year-old group. Despite these changes, the oxygen saturation levels remain consistently high across all age groups, ranging from 96% to 99%. The sweat rate, on the other hand, shows some variations in this set of measurements. The values range from 11% to 18%, with the highest sweat rates recorded for the 11 and 12-year-old groups. This suggests that these age groups may experience a higher level of perspiration, potentially due to increased exertion or environmental factors.

**Table 5: Before the Activities**

| Age | Body Temp | BPM | SpO2 | Sweat Rate |
|---|---|---|---|---|
| 7 years old | 35.64°C | 78 | 96% | 12% |
| 8 years old | 36.13°C | 73 | 100% | 10% |
| 9 years old | 36.13°C | 74 | 99% | 12% |
| 10 years old | 35.66°C | 70 | 99% | 12% |
| 11 years old | 35.64°C | 72 | 100% | 14% |
| 12 years old | 35.64°C | 74 | 99% | 16% |

*Temp=Temperature, BPM= Beat per Minute, SpO2= Saturated Oxygen Level

**Table 6: After the Activities**

| Age | Body Temp | BPM | SpO2 | Sweat Rate |
|---|---|---|---|---|
| 7 years old | 37.30°C | 130 | 96% | 13% |
| 8 years old | 37.22°C | 116 | 98% | 11% |
| 9 years old | 36.72°C | 110 | 98% | 12% |
| 10 years old | 36.62°C | 110 | 99% | 16% |
| 11 years old | 36.55°C | 110 | 98% | 18% |
| 12 years old | 36.45°C | 109 | 97% | 18% |

*Temp=Temperature, BPM= Beat per Minute, SpO2= Saturated Oxygen Level

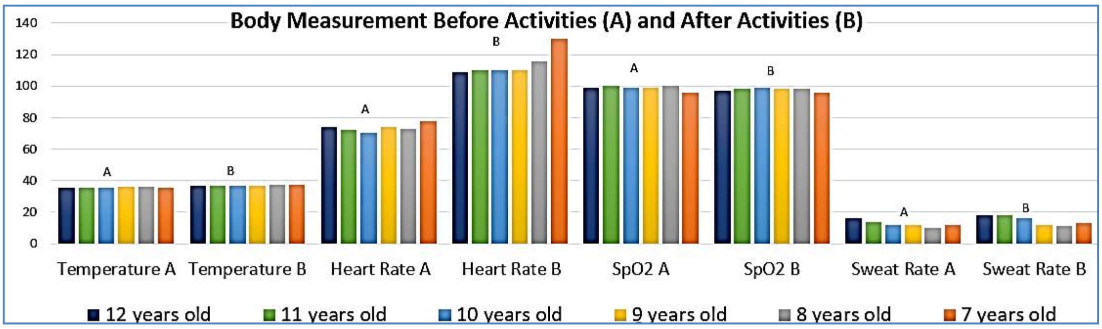



**Figure 9: Comparison graph of before and after measurement test**

Figure 9 shows the comparison graph between the measurements before activities and after activities that have been conducted in the school area. The initial A indicates as measurement reading before activities meanwhile initial B indicates the measurement recorded after the activities. Firstly, there is a slight increase in body temperature compared to the previous measurements in Temperature A. First, the body temperature shows an overall increment in body temperature from the first measurement to the second measurement for all age groups. The extent of the increase varies, with the highest temperature recorded for the 7-year-old group. This suggests a rise in body temperature after engaging in the activities at the school hall in the morning. Meanwhile, heart rate (bpm) shows some variations between the two measurement conditions. While there are both increases and decreases in heart rate values, no consistent trend can be observed across the different age groups. It is important to note that individual variations and factors like physical exertion during the activities could contribute to these fluctuations. In addition, the SpO2 levels remain relatively stable between the two measurements for most age groups, with no significant changes observed. The recorded values indicate that oxygen saturation levels are maintained within a healthy range both before and after the activities. Furthermore, by comparing the sweat rate measurements, there is a slight increase in sweat rate for some age groups in the second measurement. The 7-year-old group shows a higher sweat rate after the activities, suggesting increased perspiration during physical exertion. However, for other age groups, the sweat rate remains relatively similar before and after the activities. Overall, the comparison between the two tables indicates that engaging in activities at the school hall in the morning can lead to an increase in body temperature, possibly due to increased physical exertion. The heart rate, SpO2 levels, and sweat rate show some variations, but no clear patterns emerge across the different age groups.

## 4. Conclusion

This work successfully simulated and monitored various parameters, such as body temperature, heart rate, oxygen saturation, sweat rate, the surrounding temperature, and humidity using Arduino IDE. The microcontrollers accurately measured and displayed these readings in real-time on LCDs and through the Blynk application. The integration of these features within a single system is a significant milestone in heat stroke detection technology, particularly benefiting vulnerable children. The robust and user-friendly monitoring system, incorporating IoT technology, allows both children and parents to actively track body measurements and environmental conditions. This system provides reliability, accuracy, and real-time monitoring, offering assurance to parents, caregivers, and healthcare professionals. Prompt detection and response to abnormalities in vital signs or environmental factors mitigate the risks associated with heat-related illnesses, promoting the well-being and safety of children. By integrating advanced monitoring technologies, IoT capabilities, and user-centric design principles, this system holds promise in safeguarding children's health and safety in heat-prone environments. The device can detect heat stroke risk with an accuracy ranging from 98.46% to 99.87%, providing early alerts to prevent heat stroke occurrences.

## Acknowledgement

The authors would also like to thank the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for its support.

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