

Motor Vibration and Temperature Detector by Using IoT

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DOI: <https://doi.org/10.30880/eeee.2025.06.02.042>

Article Info

Received: 20 June 2025

Accepted: 2 August 2025

Available online: 30 October 2025

Keywords

Temperature Sensor, Vibration
Sensor, Three Phase Motor, Electric
Motor

Abstract

The project includes the description and deployment of a real-time Motor Vibration and Temperature Detector based on Internet of Things (IoT) technology which is designed to prevent sudden motor failure and preventive maintenance. This system is implemented by the use of ESP32 microcontroller in combination with temperature sensors, DS18B20 and vibration sensor, ADXL335. Critical thresholds were set at 55°C for temperature and 0.5G for vibration based on NEMA and ISO 10816 standards. In an experimental test, the system was able to warn over hazardous conditions that occurred when the vibration was above 0.5G and temperature was above 38.0°C at 2541.6 RPM. The results indicated that the parameters did not pose any danger at low speeds which at 0.01G and 36.1°C when 100.35 RPM but only became "Hazard" when speed was increased. This information was shown on a local 20x4 LCD display as well as through the Blynk service and buzzer initiated in case of critical events. The system was found to have a 100% achievable level in detecting abnormal conditions to predetermined thresholds and have the possibility of saving time to be incurred in event of downtimes since it has the ability to warn of the onset of those abnormalities. This type of solution based on the IoT allows the company to introduce a cost effective, scalable monitoring of the condition of the motors, contributing to the transformation of the maintenance strategies in industry turning reactive maintenance to predictive.

1. Introduction

The reliability and efficiency of industrial motors are crucial in modern industries to ensure uninterrupted operations and reduce costs associated with unplanned maintenance and downtime. A significant challenge in maintaining motor health is the inability to predict mechanical failures caused by excessive vibration or temperature. Such unpredictability often results in operational disruptions, higher maintenance costs and increased dependency on standby motors. Therefore, sensor is needed to help in monitoring and maintaining motor. One of the main forces behind Industry 4.0 and the Internet of Things, IoT in workplaces and factories is sensors.

Furthermore, IoT-driven predictive maintenance offers additional benefits such as better resource allocation, reduced maintenance expenses and the ability to adapt to diverse industrial applications. With the integration of sensors and IoT platforms, maintenance practices are shifting from reactive to predictive, aligning with industry trends towards smarter and more efficient operations. In this project, the focus is on developing a Motor Vibration and Temperature Detector by using IoT to address the challenges of motor maintenance in industrial settings. This system will utilize sensors to measure and analyze motor vibration and temperature, aiming to provide an effective early warning system for potential motor breakdown.

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Incorporating IoT with sensors such as DS18B20 and ADXL335 can provide continuous condition monitoring and early warnings. According to NEMA MG 1-1998, temperatures above 80°C can degrade motor insulation, while ISO 10816-3 suggests 0.5G as a safe vibration threshold for medium-sized motors. This project aims to address this challenge through an IoT-based motor monitoring system.

The issue occurs during my internship program where a problem happens when a motor's vibration and temperature cannot be predicted during breakdown. A constant checkup must be done in order to maintain the motor work progress before it fails to run. This activity will affect the time and other activities since the motor cannot be left and must be monitored from time to time. Other than that, it is going to give impacts on the maintenance fees because when a motor breaks down, it must be repaired and another motor must be used to switch and replace the position of the old one. It will increase the expenses more than usual because a stand-by motor must always be prepared and repairing fees for break down motors must always be considered. Lastly, it requires more people to perform routine maintenance and finish certain tasks. Therefore, this motor vibration and temperature detector is being made to control the motor from breakdown and fail to run by monitoring using IoT. The objective of these projects are : to develop an IoT-based prototype using ESP32, DS18B20, and ADXL335 for motor health monitoring, to visualize data remotely via the Blynk platform for real-time fault detection, Next, to test and validate the system's accuracy in identifying hazardous conditions.

2. Literature Review

2.1 Review of Electric Motor

An electric motor changes electrical energy into mechanical energy by using a magnetic field created from electric current in wire coils to turn the motor shaft. While similar in design, a generator does the opposite where it turns mechanical energy into electricity. Electric motors can be powered by alternating current (AC) from generators or power grids or direct current (DC) from batteries or rectifiers. They are categorised according to their output, design, use and power source. Motors can operate on single-, two- or three-phase power and can be brushed or brushless, DC or AC. In addition, they can be axial or radial in shape and employ liquid or air cooling [1].

2.2 Limit of Temperature for Electric Motor

A motor's performance and lifespan are greatly influenced by its operating temperature. In general, it is better if the motor body's temperature stays below 80°C. When the motor body temperature rises over this point, it suggests that the motor's winding temperature is probably high as well and may be reaching 80°C [2]. This elevated temperature can cause few effects to the motor itself such as winding insulation degradation and bearing lubricant issues. The rise in temperature for electric motors has been defined by the National Electrical Manufacturers Association (NEMA) in Motors and Generators, NEMA standard MG 1-1998 [2][3]. However, as to set an early warning temperature, the best practice to apply is by using 80-85% of insulation class temperature limit.

2.3 Review on NEMA

A set of guidelines for electric motors was created by the National Electrical Manufacturers Association (NEMA) and it covers design classes, frame dimensions, enclosures, and configurations. As for this topic will only focus on NEMA Motor Insulation Classes. The NEMA motor insulation classes explain how well a motor's winding can tolerate heat. The permitted rise beyond an ambient temperature of 40°C is specified by the four most prevalent classes which are mentioned in Table 1 [4]. The heat resistance grade of the insulating materials used in an electric motor is indicated by the insulation class. The maximum temperatures, winding temperature rise and hot-spot over temperature allowance restrictions for each of these classes which are A, B, F, and H are as Table 1 [2] and [4].

Table 1 Temperature limits based on insulation class

| Insulation Class | A | B | F | H |
|--|-----|-----|-----|-----|
| Maximum Allowable Temperature (°C) | 105 | 130 | 155 | 180 |
| Winding Temperature Rise Limit (°C) | 60 | 80 | 105 | 125 |
| Hot-spot Over Temperature Allowance (°C) | 5 | 10 | 10 | 15 |

The rise in temperature above the ambient temperature is known as temperature rise. The temperature of the air in the area surrounding the motor is known as the ambient temperature where it is sometimes referred to as "room temperature." The hot spot over temperature allowance is the additional heat limit permitted at a motor or transformer's hottest point to ensure that it remains safe and does not overheat while in regular operation [5]. The overall temperature or the maximum allowable temperature of a component is the sum of the temperature

rise, hot-spot over temperature allowance and ambient temperature. The general temperature determines the insulation temperature classes.

3. Methodology

This section explains and depicts the techniques and procedures used throughout the project's conception and development. The method's description should be more detailed before it is implemented. Therefore, this section will be used to review the project's block diagram, title, problem definition, and software and hardware choices.

3.1 Proposed Design

This real connection of Fig. 1 that demonstrated in this sketch explains how a 3-phase motor is connected with monitoring sensors and microcontroller system. In order to measure operating temperatures, the DS18B20 temperature sensors are positioned at key locations of the motor which on its body and will give signal to the buzzer if the temperature of the motor is reaching the limit. These sensors are wired to the ESP32 microcontroller that analyses this data acquired by the sensor. The ADXL335 vibration sensor is placed on body of the motor as a way monitoring high levels of vibrations which may signal mechanical problems such as imbalance or wear. The whole system is housed in an enclosure protective box with the ESP32 microcontroller and an LCD screen inside. The LCD is employed to give actual time feeds on the set temperatures and vibrations where it will give a warning such as 'Hazard' if the level exceeds the allowable limit and "Safe" when the sensors is within limit. Meanwhile, the ESP32 will send a signal to the Blynk Application as it can also display the status of motor condition towards its vibration and temperature. This configuration guarantees dependable motor monitoring, facilitating prompt reactions to potentially hazardous situations to safeguarding the motor and adjacent equipment.

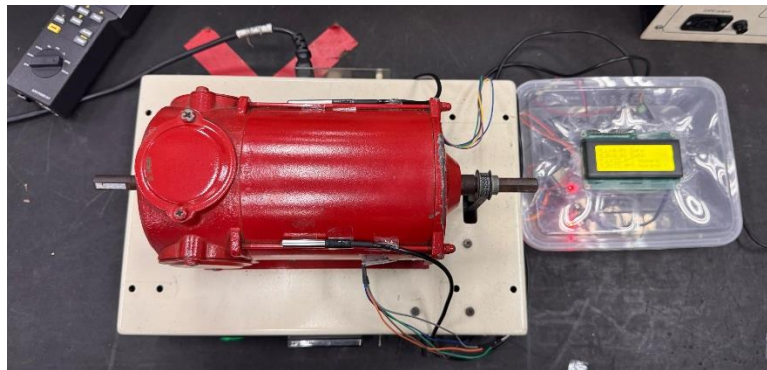


Fig. 1 *Prototype of project design*

3.2 System Flowchart of Overall Project

Fig. 2 illustrates the step-by-step process for designing and integrating a solar power system. It begins with stating design specifications, followed by mathematical calculations to determine component specifications, including solar panels, batteries, and SPWM inverters. A circuit diagram is created in MATLAB to visualize component relationships, and adjustments are made if specifications are not met. Once finalized, components are procured and integrated into the hardware architecture. The SPWM inverter code is programmed, tested, and uploaded to an Arduino Uno, with troubleshooting as needed. Each component is individually tested before assembling the system, which is installed at Jalan Lestari, UTHM. Final system connections and coding are aligned, and operational data is collected to evaluate the system's efficiency and effectiveness, concluding the process.

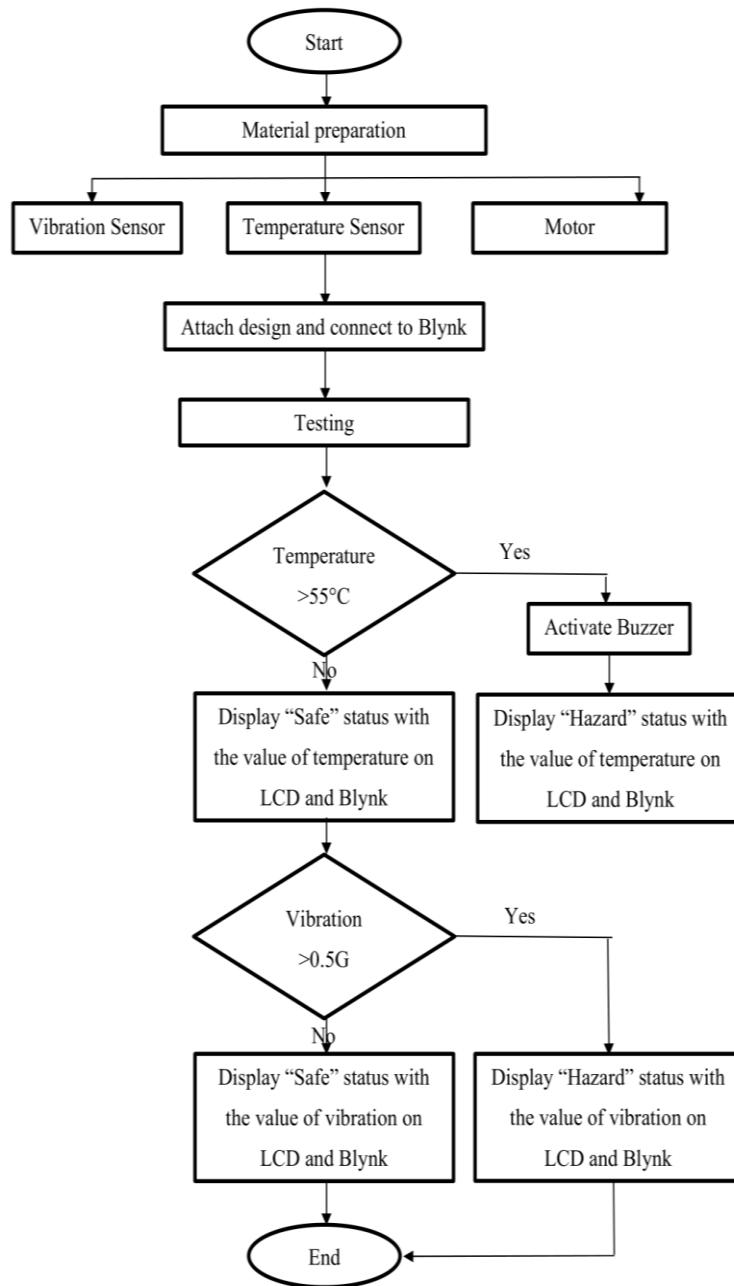


Fig. 2 Flowchart of the project

3.3 Design Connection and Testing

This project involves monitoring a three-phase motor using a temperature sensor and a vibration sensor connected to an ESP32 microcontroller. All components, including an LCD for local data display and a connection to the Blynk app for remote monitoring, are initialised by the ESP32. While the vibration sensor (ADXL335) detects movement from underneath the motor to prevent interference, the temperature sensor (DS18B20) measures heat. The system marks the temperature as "Hazard" and notifies the user via the LCD and Blynk if the temperature rises beyond 55°C or the vibration level reaches 0.5G. In the case of extreme temperatures which in Hazard condition, a buzzer will get triggered. By identifying overheating or instability early on, this configuration seeks to promote predictive maintenance and avoid motor failure.

4. Result and Analysis

The results of the IoT-based Motor Vibration and Temperature Detector project are shown in this part. The outcomes show that the system can precisely track and identify unusual vibration and temperature levels in a three-phase motor in real time. Continuous remote monitoring is made possible by the display of sensor data on

the Blynk IoT platform and an LCD screen. These outcomes support the objective of increasing maintenance efficiency and decreasing operational downtime by validating the system's efficacy in delivering early warnings for possible motor breakdowns.

4.1 Vibration Sensor Test

The IoT project test results for vibration sensor are shown in Table 2. Six test points were selected based on varying motor speeds. Sensors were mounted on left and right sides of the motor to capture data from both ends. Data represents readings from multiple runs of various speeds in RPM. This setup helps identify any spatial variation in motor condition. The "Safe" and "Hazard" conditions were decided based on the size, type and application of an electric motor all affect its vibration limit which is represented in units of acceleration (G). General recommendations are usually based on ISO standards which are ISO 10816 and ISO 20816 that categorize vibration intensity in velocity (mm/s or in/s RMS) [6]. However, G values are used in some industries, particularly for high-speed or precision equipment.

Table 2 *Vibration sensor test*

| No. | RPM | Position | Result | Status |
|-----|---------|----------|--------|--------|
| 1 | 100.35 | Left | 0.01 | Safe |
| | | Right | 0.01 | Safe |
| 2 | 502.63 | Left | 0.04 | Safe |
| | | Right | 0.03 | Safe |
| 3 | 1003.70 | Left | 0.06 | Safe |
| | | Right | 0.07 | Safe |
| 4 | 1538.6 | Left | 0.22 | Safe |
| | | Right | 0.28 | Safe |
| 5 | 2003.3 | Left | 0.68 | Hazard |
| | | Right | 0.72 | Hazard |
| 6 | 2541.6 | Left | 1.66 | Hazard |
| | | Right | 1.81 | Hazard |

From Table 2, it shows the vibration sensor test results from the left and right sides of the motor at various motor speeds, RPM. The vibration readings stayed low which is below 0.5G at lower speeds, between 100.35 RPM to 1538.6 RPM and the status was recorded as "Safe." Nevertheless, the vibration levels grew well over the 0.5G threshold when the motor speed increased to 2003.3 RPM and 2541.6 RPM, with measurements reaching 1.81G which led to a "Hazard" designation. This suggests that increased motor speed causes more vibration and the sensor was able to pick up on these variations. The findings support the system's ability to precisely measure vibration levels and issue early alerts when dangerous situations arise, hence reducing the risk of motor damage.

4.2 Temperature Sensor Test

The IoT project test results for temperature sensor are shown in Table 3. Different motor speeds led to the selection of six test points. To collect data from both ends, sensors were installed on the motor's left and right sides. Readings from several runs at different RPM speeds are represented by the data. The rise in temperature for electric motors has been defined by the National Electrical Manufacturers Association (NEMA) in Motors and Generators, NEMA standard MG 1-1998 [1][7][8][9]. However, to set an early warning temperature, the best practice to apply is by using 80-85% of insulation class temperature limit.

Table 3 *Temperature sensor test*

| No. | RPM | Position | Result | Status |
|-----|--------|----------|--------|--------|
| 1 | 100.35 | Left | 36.1°C | Safe |
| | | Right | 36.9°C | Safe |
| 2 | 502.63 | Left | 35.9°C | Safe |
| | | Right | 36.9°C | Safe |
| 3 | 1003.7 | Left | 36.0°C | Safe |
| | | Right | 36.8°C | Safe |
| 4 | 1538.6 | Left | 35.9°C | Safe |
| | | Right | 36.6°C | Safe |
| 5 | 2003.3 | Left | 36.2°C | Safe |
| | | Right | 37.1°C | Safe |
| 6 | 2541.6 | Left | 38.8°C | Hazard |
| | | Right | 38.9°C | Hazard |

Table 3 shows the temperature sensor test results at different motor speeds in RPM, measured on both the left and right sides of the motor. All temperature readings remained within the safe range, below the predetermined limit of 55°C, with values between 35.9°C and 37.1°C, from low to moderate rates. However, temperatures reached 38.8°C a left side and 38.9°C at right side, at the maximum speed tested 2541.6 RPM, resulting in a "Hazard" designation. The system accurately detected the increasing trend and flagged these data as possible warnings.

4.3 Hardware Development

In Fig. 4., temperature and vibration data remained low and well below the threshold values at a low motor speed of 100.35 RPM. This state was categorised as "Safe," meaning that there were no indications of high heat or mechanical stress and the system was stable.



Fig. 4 Result of 100.35 RPM

Based on Fig. 5, temperature and vibration levels increased slightly yet remained within an acceptable range as the motor speed increased to 502.63 RPM. The system maintained its "Safe" rating, confirming reliable motor operation at moderate load.



Fig. 5 Result of 502.63 RPM

The system detected slight increases in both sensor readings at 1003.7 RPM as shown in Fig. 6 but these values remained within the predetermined ranges. The "Safe" status confirmed the motor was operating efficiently without risk of failure at this speed.



Fig. 6 Result of 1003.7 RPM

Vibration readings reached the top limit but stayed below 0.5G when the motor was operating at 1538.6 RPM in Fig. 7. The status remained "Safe" despite being near the threshold, demonstrating the system's capacity to withstand faster speeds without losing stability.



Fig. 7 Result of 1538.6 RPM

As shown in Fig. 8, a "Hazard" alert was triggered when the vibration levels surpassed 0.5G at 2003.3 RPM. This was a crucial moment where maintenance care might be needed because it signalled the beginning of potentially harmful mechanical conditions. However, the temperature is not yet triggering the "Hazard" signal since it is still below the set temperature which in this experiment is 38.0°C.



Fig. 8 Result of 2003.3 RPM

Result of RPM value for both vibration and temperature readings above the danger criteria in these data that illustrate in Fig. 9 which correspond to the maximum tested speed of 2541.6 RPM. The system flagged a "Hazard" condition, demonstrating its effectiveness in detecting high-risk states and the need for immediate action to prevent motor damage.

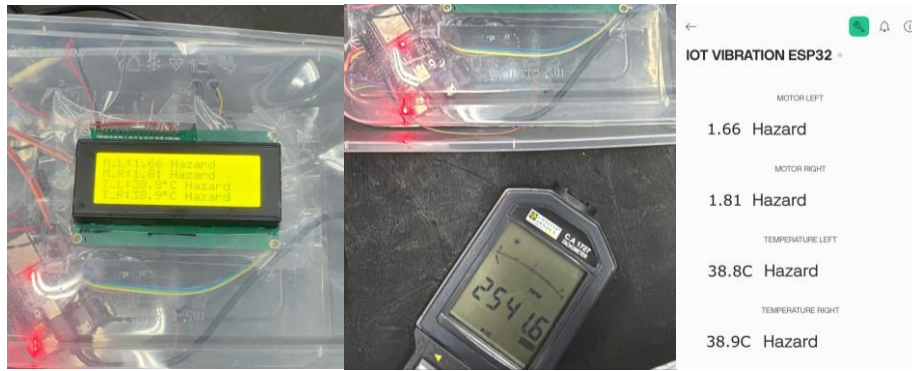


Fig. 9 Result of 2541.6 RPM

4.4 Results of Temperature vs. RPM

This graph illustrates in Fig. 10 shows the relationship between motor speed (RPM) and temperature recorded on both the left and right sides of the motor. Particularly at higher speeds, the temperature progressively rises in line with the RPM. To show the highest safe temperature, a threshold line is placed at 38°C. According to the graph, both temperature measurements stay below the limit at lower RPM but surpass 38°C at the maximum speed of 2541.6 RPM, resulting in a "Hazard" status. This illustrates how the system may identify overheating when working at high rates.

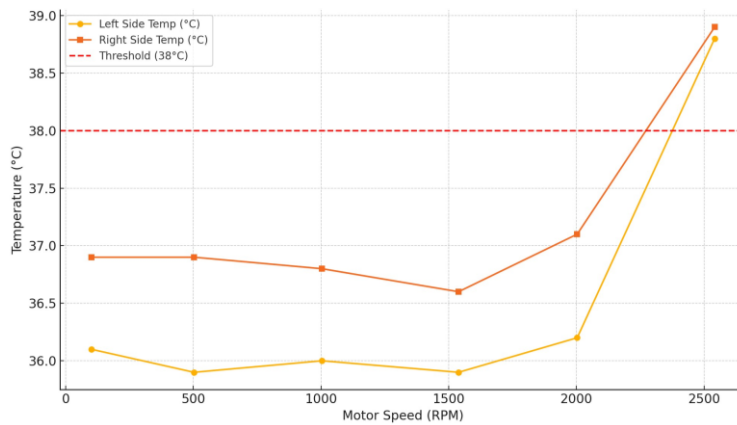


Fig. 10 Temperature vs. RPM (Left and Right Side)

4.5 Results of Vibration vs. RPM

Fig. 11 shows the vibration levels measured by the left and right sensors on a motor at different RPM speeds. Both sensors show a steady increase in vibration levels as the RPM rises. Safe motor operation is indicated by vibration readings that stay below the 0.5G hazard level at low speeds which at 100.35 to 1538.6 RPM. Both sensors, however, pick up vibrations that surpass the threshold when the motor hits higher speeds at 2003.3 RPM and above which could indicate a mechanical problem. This demonstrates the significance of real-time monitoring for early warning and maintenance by confirming that greater motor speeds can result in dangerous vibration levels.

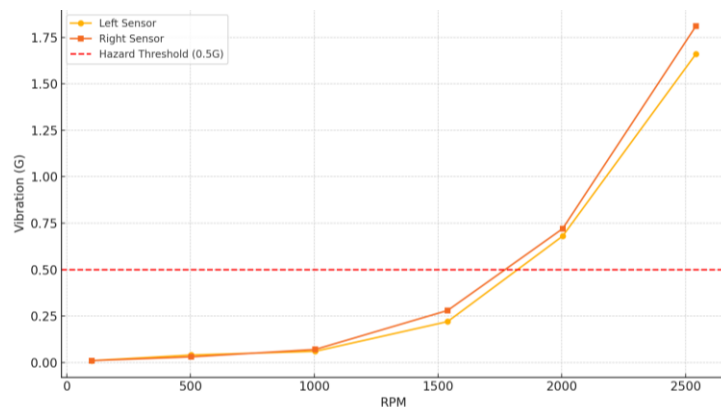


Fig. 11 Vibration vs. RPM (Left and Right Side)

5. Conclusion

The project titled “Motor Vibration and Temperature Detector Using IoT” presents the design and implementation of a system that monitors the operational health of industrial motors through real-time vibration and temperature analysis. To identify abnormalities in motor behaviour, the system integrates an ESP32 microprocessor with DS18B20 temperature sensors and an ADXL335 vibration sensor. The data is sent to the Blynk IoT platform for remote monitoring, and a 20x4 LCD shows the measurements locally. The system notifies users by updating the status display and sounding a buzzer alarm when abnormal levels are detected, such as temperatures above 55°C or vibrations above 0.5G. Reducing unexpected motor failures, reducing maintenance expenses, and facilitating the switch from reactive to predictive maintenance are the goals of this Internet of Things-based solution. The prototype's ability to recognise dangerous situations was validated through experimental testing in both simulated and real-world settings, proving that it can be helpful in improving operational safety and motor performance monitoring.

Acknowledgement

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

Conflict of Interest

Author declares that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of result and manuscript preparation.

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