Ambulance tracking system using GPS module and IoT based telegram messenger to find fastest route

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ABSTRACT

Traffic congestion in urban areas affects ambulance trips to hospitals. This research aims to find the fastest route for ambulances to travel. The fastest route has criteria such as road shape, road width, shortest distance traveled, and fewer road users. This detection system applies internet of things (IoT) technology to each ambulance equipped with global positioning system (GPS), NodeMCU, and Wi-Fi modem that can send GPS coordinates to the cloud server, which will then mark the shortest distance from its current location to the hospital through the place where the emergency call is raised. The components used in this research are Neo6M GPS, NodeMCU ESP8266, cloud computing, and smartphone. This system can provide realtime information on all ambulance positions via android applications and Telegram messenger. The results obtained can determine the fastest path, distance, and travel time. In addition, the operation of this system takes 2-3 minutes to find the GPS signal at the beginning, then there is a 1-2 second delay from the GPS Tracking movement. Testing the route accuracy of this system and google maps by driving by motorcycle shows the results of this GPS system are more accurate in terms of distance and travel time.

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1. INTRODUCTION

Traffic congestion has long been a serious challenge in densely populated cities and countries [1]. The yearly increase in vehicles without proportional road widening or the addition of overpasses is a primary driver of gridlock. Governments have attempted various policies such as traffic management and odd even license plate schemes, but the impact has not been significant [2]. The consequences are critical when rapid response is needed for paramedic motorcycles, ambulances, and other emergencies. The speed of assistance for patients who require ambulance services is one of the determinants of patient safety. To address these issues, a system is needed to monitor road user conditions using the global positioning system (GPS) and internet of things (IoT) [3]. Typical implementations employ a GPS module and a NodeMCU connected to Google Maps and cloud computing to collect information about paramedic vehicles, a process commonly referred to as tracking. The accuracy of location detection, including latitude and longitude, is a key factor in developing such a system [4].

A substantial body of work has explored GPS based IoT for position tracking [5]. GPS is a satellite navigation system that provides location and time information in all weather conditions anywhere on the earth's surface, provided a receiver has coverage from at least four satellites [6]. The IoT is a global network infrastructure that links physical and virtual objects through data capture and communication technologies, building on existing networks and the internet and their extensions [7]. GPS architecture comprises three segments, the space segment, the control segment, and the user segment, with a total of 24 satellites orbiting the earth, 21 active and 3 on standby. These satellites receive and store data from control stations, maintain highly accurate time with onboard atomic clocks, and continually transmit signals and information to receivers [8].

Multiple studies report mature solutions and performance metrics. A vehicle security system that tracks locations in real time and controls the engine through Telegram achieved a very fast response time of 2.776 seconds, and the best distance performance between Google Maps and GPS with a success rate of 97.35% and an error rate of 2.65% [9]. Another study monitored traffic and assisted paramedics and ambulances to navigate the fastest routes using Arduino based circuits by sending GPS coordinates and guiding vehicles along server defined paths that save time [10]. An Ambulance Tracker application was shown to improve the efficiency and effectiveness of emergency medical interventions, ultimately saving lives and improving patient outcomes [11]. GPS based vehicle tracking has opened a new era of communication across transportation systems. According to the National Crime Records Bureau, nearly 24,012 people die every day due to delays in timely medical assistance [12]. Efficient tracking systems have also been developed using NodeMCU ESP8266 and GPS modules to provide real time location tracking, speed monitoring, and remote-control capabilities by extracting accurate latitude and longitude coordinates [13], [14].

The performance of the Neo 6M module has been evaluated, showing a distance difference of about 1 to 2.5 meters compared with readings from Google Maps or smartphones. Under good network conditions, the average delay was 0.326 seconds and the throughput of data transmission using NodeMCU reached 140.4 bytes per second over 150 seconds [15]. A mobile application for bus tracking reduced passenger waiting time, detected route deviations and unwanted stops, and analyzed GPS coordinates for three buses labeled A, B, and C [16]. Ambulance tracking system technology helps hospital administration prepare actions before the patient arrives by combining GSM and GPS with a low-cost microcontroller such as Arduino to coordinate the modules [17]. A continuous GPS tracker using a NodeMCU ESP8266 was also designed for locating missing girls and children by placing the device in a bag or pocket to obtain their location [18]. A continuous GPS tracker is designed with the help of NodeMCU ESP-8266 board. In this project, we can find the location of missing girls and children. Moreover, with this product we can find their location by keeping this device in their bag/pocket or elsewhere [19].

Other real time solutions integrate IoT, vehicle to everything communication, and vehicular ad hoc networks. Hardware such as Arduino Uno R3, SIM800L, and NEO 6M works with Node.js, sockets, and Firebase for seamless real time GPS data collection, storage, and visualization on a web interface. Node.js and sockets enable efficient hardware software communication, while Firebase provides real time storage and synchronization for resource management and tracking [20]. Another system displays vehicle locations on Google Maps using an Arduino Mega microcontroller with an Ublox NEO 6M GPS module and a SIM900A GSM module to interact with users, aimed at tracking vehicles when a motorcycle is stolen or lost [21]. An IoT based helmet security system with tracking features for Android detected helmet theft at a maximum Bluetooth master to slave range of 10 meters, with average hardware to Firebase transmission time of 1.1 seconds, and supported monitoring and tracking through Android Jelly Bean applications [22]. A smartphone-based motorcycle security device using an Ublox 6M GPS module reported safe monitoring accuracy up to 95% [23]. An internet-based accident detection, tracking, and handling system that integrates Telegram and SMS, called AcciDet TracSys and AcciAddr TracSys, addressed a gap in prior work that only detected accidents without coordinating ambulance arrival, and testing across different gravity force levels indicated reduced fatal incidents [24]. Another prototype connected an Arduino uno, a Neo 6M GPS module, and an ESP8266 Wi-Fi module to send data to ThingSpeak as a cloud application programming interface (API) service for storage and analysis [25].

Further tests demonstrated that an SMS based tracking system using an Ublox Neo 6M GPS module and a SIM800L module can help secure valuable assets such as motorcycles and bags by sending GPS coordinates to a designated phone number [26]. Limitations in existing tracking devices, such as the inability to verify route adherence, were addressed by a prototype that adds route deviation detection, an emergency button, and a STATUS command that prompts the device to send the current location via SMS [27]. In general, GPS and GSM based tracking technologies have transformed vehicle monitoring by enabling remote observation, which improves safety, operational efficiency, and cost effectiveness [28]. For small scale areas, a wireless sensor network approach using a Neo 6MV2 UBLOX GPS module and the enhanced ShockBurst protocol with an NRF24L01 plus PA LNA module provided tracking without relying on Wi-Fi or GSM infrastructure and serves as an alternative network in constrained scenarios [29]. A prototype for object tracking that provides location information for both stationary and moving items, including keys and vehicles, demonstrates potential applications in transportation and security [30].

From the reviewed literature, ranging from reputable international journals to accredited national journals, the authors found no reports on GPS response time measured from device power on to operational readiness, and no comparisons between GPS tracking accuracy and Google Maps tracking as a proxy for real world travel time on roads. This study addresses those gaps by measuring initial GPS response time, comparing GPS accuracy against Google Maps, presenting many GPS coordinates simultaneously within the application, and sending GPS coordinate information to Telegram upon request. Collectively, these elements constitute the novelty and contribution of this research in relation to prior work.

2. METHOD

To explain the method of the IoT based ambulance tracking system research on tracking systems using GPS modules and Telegram messengers, the author describes it in the form of a flowchart. There are two flowcharts that can describe the method of the system under study. Figure 1 illustrates the flow of sending location data to the server. The GPS module searches for location coordinates by utilizing signals captured from satellites, then the location coordinate data obtained will be verified first whether the location coordinate data is valid or not. When the location coordinate data is valid, the NodeMCU will send the location coordinate data to the server and the server will provide the last location coordinate data to be forwarded to the user. The process of retrieving data to the server by the user can be seen in Figure 2.

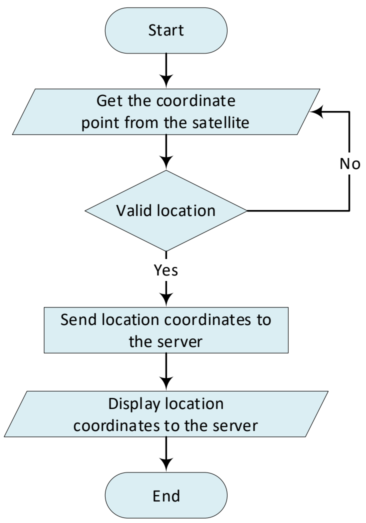


Figure 1. Flowchart of sending location data

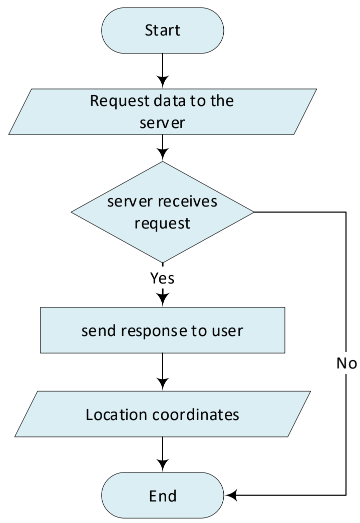


Figure 2. Data retrieval process from the server

Figure 2 illustrates the process of retrieving data from the server. The user will send a data request to the server and when the server receives a data request from the user, the server will display the last location coordinate data sent by the NodeMCU. After making a system work design, the next researcher makes an IoT system design. The IoT system design is a derivative in the form of technical system work and device form. This design can be seen as in Figure 3.

Figure 3 is the design scheme of the GPS device that will be made in this study. The device will later be placed on an ambulance motorcycle so that the ambulance can be monitored at its last location point. The device uses the following devices:

– NodeMCU ESP8266, as the controller of all connected devices. The NodeMCU microcontroller is the main part that functions to control the entire system. NodeMCU is an opensource IoT module platform. Consists of hardware in the form of the ESP8266 System on Chip from the ESP series made by Espressif Systems. NodeMCU also has a Wi-Fi device so that it can connect to the internet. In this case the Wi-Fi node sends signals to the hosting server and the Telegram messenger Api bot.
– GPS Neo 6M, as a satellite signal receiver.
– Portable Wi-Fi, as a provider of internet needs to NodeMCU.
– Red 5 mm F3 LED light, as an indicator connected to Wi-Fi.
– Yellow 5 mm F3 LED, as an indicator that it is connected to the satellite.

– Hosting, as a communication intermediary between NodeMCU and the Telegram messenger Fire Bot server.
– Android App, through an application with the name “Ambulance”. It is a visual container to see the location of the ambulance and its movement.

In addition to hardware this system is also designed with software for the control process. Android-based software that will be built with android studio programming. Tracking data by GPS will appear on the android application with the name of the application Ambulance with data in the form of a road map and ambulance location. In addition, this system is also designed to provide information to Telegram messenger.

Next is the process of making the device. The process of making the device is done by connecting each component using jumper cables to the ESP8266 MCU module to the Neo 6M GPS module, indicator lights, and portable Wi-Fi devices. Furthermore, the NodeMCU is synchronized with hosting so that the IoT process can run on the data flow to Maps and Telegram messenger. The device made as many as 3 units, each unit will be placed on 3 ambulance motorcycles, as shown in Figure 4. Each unit is named ambulance1 (GPS1) as shown in Figure 4(a), ambulance2 (GPS2) as shown in Figure 4(b), and ambulance3 (GPS3) as shown in Figure 4(c).

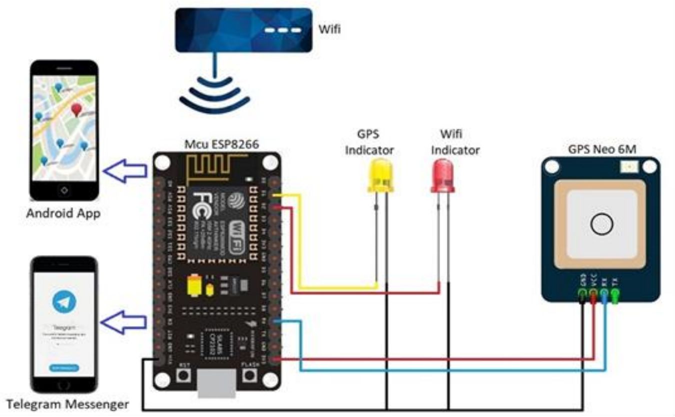
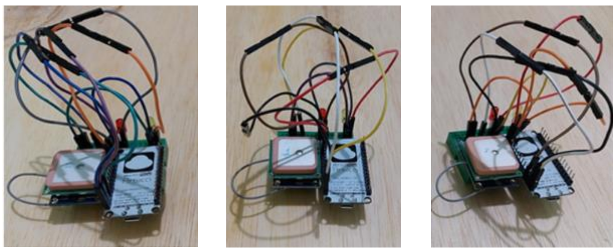


Figure 3. Schematic design of GPS device



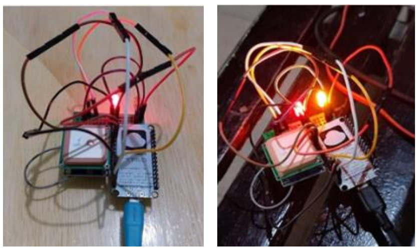
(a) (b) (c)

Figure 4. The result of making 3 device units of (a) ambulance1 (GPS1), (b) ambulance2 (GPS2), and (c) ambulance3 (GPS3)

3. RESULTS AND DISCUSSION

The device that has been assembled and programmed with Arduino programming ideas can provide information on the location of the hospital and the three ambulances, in addition to detailed information on the coordinates of each ambulance can also be done via Telegram messenger. This Android-based application itself is built with the react native framework. These three ambulances can be seen moving the location point according to the movement of the GPS device motorcycleried. Delay of device movement with maps is 1-2 seconds. This condition will continue until the GPS device is turned off or the ambulance has arrived at the destination hospital. This Microcontroller device when working can be seen as in Figure 5. Where in Figure 5(a), shows that the device is connected to Wi-Fi by turning on the red indicator light. Then in Figure 5(b) the device is connected to Wi-Fi and GPS with red and yellow indicator lights on. The application of indicator lights is motorcycleried out to determine the performance of the device. In this study, the GPS indicator light will turn on every 5 seconds, if within 5 seconds it does not turn on, it means that there is a disconnection with the satellite.

After the device is connected to Wi-Fi and GPS, then the hospital points information and the location of the three ambulances can be seen at once in the android application that has been made. This research is able to answer the shortcomings of previous studies where the GPS location point cannot be detected at once from several GPS, so that the display of GPS points does not appear all in the application. The testing process motorcycleried out in the city of Banda Aceh in September 2023 shows the location of the hospital on the road at Ujung Bate I road with coordinates 5.537953, 95.309577, the location of ambulance1 on Ujung Bate I road with coordinates 5.539077, 95.310423, ambulance2 on Cemp road with coordinates 5.550081, 95.310778, and ambulance3 on Medan Banda Aceh Road with coordinates 5.553611, 95.295330, as shown in Figure 6.



(a) (b)

Figure 5. System testing of (a) the device is connected to Wi-Fi by turning on the red indicator light and (b) the device is connected to Wi-Fi and GPS with red and yellow indicator lights on

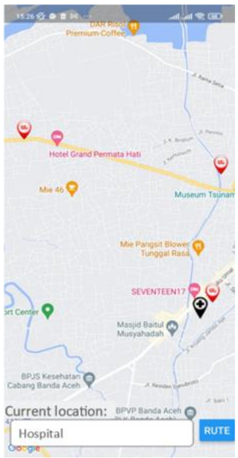
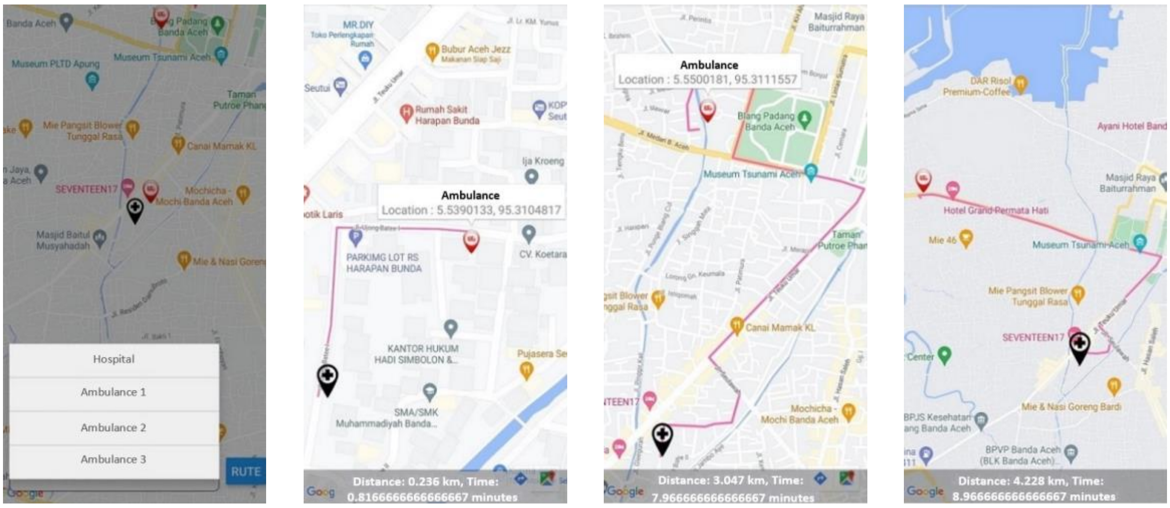


Figure 6. Detailed info of ambulance and hospital locations (3 ambulances displayed at once)

Figure 7 displaying the hospital point, ambulance, and the route from the ambulance to the hospital point. The application has been built with an initial display providing information on ambulance object data in red, and hospitals in black, a road map and a choice of hospital objects, ambulance1, ambulance2, and ambulance3 as shown in Figure 7(a). The advantage of this application and what distinguishes it from other similar studies is that all ambulances can be displayed on one map page so that it will facilitate monitoring of all ambulances in real time on one page; by displaying all ambulances on one page, the application utilizes a centralized dashboard-based user interface (UI). This concept is known in human computer interaction (HCI) to increase user accessibility and reduce cognitive load. The use of geographic information system (GIS)-based maps allows location data to be visualized interactively and in real time, which is the formation of modern monitoring. With the centralized dashboard, users can quickly make decisions based on data that is directly visible in one place so that it is very efficient in time and management. Furthermore, by determining the choice of ambulance1, the application will show a road map with the shortest route. Determination of the route also determines the distance and time which then becomes information. In this case, Figure 7(b) shows a distance of 0.236 km with a duration of 0.816 minutes. Furthermore, ambulance 2 in determining the fastest route gets information on the distance of 3.07 km with a duration of 7.96 minutes as shown in Figure 7(c). Furthermore, ambulance3 in determining the fastest route gets information on the distance of 4.228 km with a duration of 8.96 minutes as shown in Figure 7(d).



(a) (b) (c) (d)

Figure 7. Displaying the hospital point, ambulance, and the route from the ambulance to the hospital point of (a) initial map view showing hospitals and ambulances, (b) route of ambulance1, (c) route of ambulance2, and (d) route of ambulance3

In addition to distance and time information, this system also shows ambulance coordinate point information during the fastest route search process. In the process, the researchers concluded that the system can determine the fastest route in real terms with the reality in the field. In addition, this system is also applied in the city of Langsa, the results are also very realistic with reality in the field. During the experiment, the GPS device experienced satellite signal problems if it was indoors. The new GPS manages to get a satellite signal if the device is placed outdoors, then still get a signal if it is brought into the room. The GPS process in getting a satellite signal at the beginning when the device is turned on takes about 2-3 minutes. The length of time is a shortcoming of this system. Researchers in this case concluded, this is a shortcoming of the Neo 6M GPS module.

In this study, the system is also compared with Google Maps to compare the results in terms of route selection, distance details, and travel time that are more real with the reality in the field. In this case the researcher presents the comparison results in Table 1 and Figure 8. Of the six routes that researchers tried by driving using a motorcycle with optimal speed, the time shown by GPS Tracking was more accurate. The inaccuracy of google maps in this study can be seen from the route coordinates 5.537953, 95.309577 to 5.539077, 95.310423 with a distance of 236 meters showing a travel time of 3 minutes with free road conditions. While the results of the researcher's driving test on this route only took 50 seconds with an average speed of 65 km/hour. Then from the coordinate route 5.537953, 95.309577 to 5.550081, 95.310778 takes 7.90 minutes with an average speed of 60 km/hour. Finally, from the coordinate route 5.537953, 95.309577 to 5.553611, 95.295330 took 8.88 minutes with an average speed of 63 km/hour. In addition, the results of this system are also more detailed in terms of distance and time. The same was true for the other three routes.

Table 1. Comparison of results

From-coordinates	To-coordinates	Google maps	GPS tracking
5.537953, 95.309577	5.539077, 95.310423	Distance: 230 m Time: 3 minutes	Distance: 0.236 km Time: 0.816 minutes
5.537953, 95.309577	5.529236, 95.303469	Distance: 1.6 km Time: 4 minutes	Distance: 1.605 km Time: 4.610 minutes
5.537953, 95.309577	5.544379, 95.314459	Distance: 2 km Time: 4 minutes	Distance: 2.004 km Time: 5.600 minutes
5.537953, 95.309577	5.532944, 95.37045	Distance: 2.2 km Time: 5 minutes	Distance: 2.238 km Time: 6.024 minutes
5.537953, 95.309577	5.550081, 95.310778	Distance: 3 km Time: 7 minutes	Distance: 3.047 km Time: 7.966 minutes
5.537953, 95.309577	5.553611, 95.295330	Distance: 4.2 km Time: 7 minutes	Distance: 4.22 km Time: 8.966 minutes

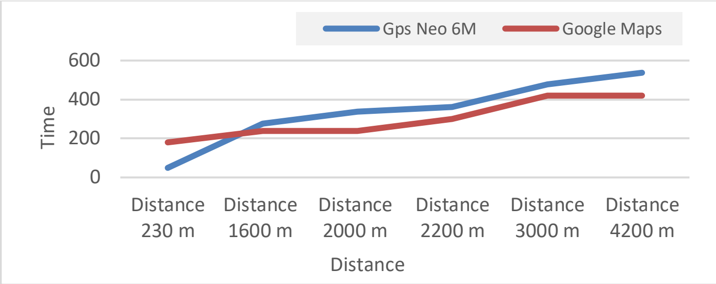


Figure 8. Comparison chart of distance and time

Apart from using the application, to see the ambulance location point can also be done via Telegram by utilizing Telegram bots. This Telegram bot is named @ambulansbot. To find out the location of each ambulance, it is enough to send a message to the Telegram bot, later the Telegram bot will send URL maps of each ambulance based on the coordinates of the ambulance's last location. Messages that can be sent and understood by Telegram bots can be seen in Table 2. After sending the command message to the Telegram bot, the Telegram bot will automatically send the URL maps of the ambulance location based on the command sent. The results of the Telegram bot simulation are as shown in Figure 9.

Table 2. Commands understood by ambulance bot Telegram

Command	Usability
/start	To display Telegram bot usage information
/ambulans1	To display the URL of ambulance maps 1
/ambulans2	To display the URL of ambulance maps 2
/ambulans3	To display the URL of ambulance maps 3

Figure 9. Simulation results using Telegram bot

4. CONCLUSION

The system that has been built can display 3 (three) GPS ambulances at once. The ambulance movement is detected in realtime in the android application with a delay of 1-2 seconds. All devices that have been made do not succeed in getting a satellite signal when started 'On' (turned on) from indoors. The GPS system will immediately get a satellite signal if it starts to be turned on outdoors, if it gets a satellite signal it will not disappear if it is brought indoors. The system has the disadvantage of finding the satellite signal at the beginning, which takes 2-3 minutes. This is felt to be quite long, but after getting a relatively stable signal, so that it can work in realtime with a small delay. From the experiments on 3 ambulances in

Banda Aceh and Langsa City, the system was able to find the fastest route, complete with distance and travel time. All routes shown by this system are in accordance with the reality in the field of the fastest routes traveled by the community to and from the same or surrounding locations. In addition to getting information from artificial applications on android can also be through telegram messenger. The information provided in the telegram messenger is in the form of link maps and the coordinates of the ambulance object, which when clicked will immediately open in the application. Then the route accuracy also shows that the GPS of this ambulance system is more valid than google maps in terms of distance and travel time. The system of this research has not yet reached the stage of monitoring route tracking as well as all ambulances. Although the system can show all ambulance positions, it is not yet at the monitoring stage that can show the route tracking of all ambulances simultaneously. This is the next plan of the author in the next research.

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AUTHOR CONTRIBUTIONS STATEMENT

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Banta Cut				✓	✓		✓	✓		✓		✓		

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
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I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest regarding the publication of this paper.

DATA AVAILABILITY

The author confirms that the data supporting the findings of this study are available in the article.

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