BOHR International Journal of Internet of things, Artificial Intelligence and Machine Learning
2024, Vol. 3, No. 1, pp. 29–37
DOI: 10.54646/bijiam.2024.22
www.bohrpub.com

REVIEW

IoT based health monitoring: A systematic review

K G. Gaya[*†] **and A. Danladi**

Department of Pure and Applied Physics, Adamawa State University, Mubi, Nigeria

[*]**Correspondence:**
K G. Gaya,
kennedygaya1@gmail.com

[†]**ORCID:**
K G. Gaya
0009-0005-1329-193X

Received: 14 June 2024; **Accepted:** 12 July 2024; **Published:** 9 August 2024

The term "Internet of Things" (IoT) describes a network that uses particular protocols and sensors to link different gadgets to the Internet. This makes it easier to communicate and exchange information, which also makes it possible to do intelligent tasks like management, tracking, recognition, and monitoring. In the healthcare industry, the use of sensor-based intensive health monitoring systems and IoT is growing very fast. However, the significance of IoT in health monitoring is not limited to individuals with medical knowledge. It involves both medical and non-medical personnel (laypersons). This review work presents a systematic review of the application of IoT-based health monitoring systems in monitoring health issues. This overview discusses the IoT-based technologies and how to use them for monitoring healthcare. Systems and gadgets with IoT capabilities are becoming significant day by day in the healthcare sector. By expanding healthcare access and lowering hospital expenses, the integration of IoT with healthcare has significantly improved patient outcomes. This analysis outlined some of the most important current applications and technology being used in the healthcare sector and gave a comprehensive overview of the state of IoT at present.

Keywords: internet of things (IoT), health care (HC), wearable sensors (WS), health monitoring (HM), artificial intelligence (AI)

Introduction

The early 2000s marked the integration of wireless and sensor network systems that facilitated the advancement of Internet of Things (IoT)-based health monitoring in the healthcare sector. In the past times, researchers have focused on monitoring systems that used basic sensors to measure patient's dynamic signs and transmit patient information to healthcare providers. As cloud computing and internet access advanced more wearable technologies and mobile applications have emerged through real-time data sharing, which brings about a significant breakthrough in health care monitoring and becoming the growing potential of analytics prediction and personalized medicine recommender which is driven by the union of AI machine learning technologies with IoT devices.

The healthcare sector has witnessed an important, significant rapid improvement in recent years with the introduction of IoT, which opened up new ideas of possibilities for remote health patient monitoring, revenue, and employment opportunities (1). The advancement of human health monitoring systems that make use of devices and sensors to constantly monitor a patient's medical data and provide real-time reports on the well-being of the patient has been one of the major uses of the Internet of Things in the healthcare industry (2).

A network of wearable sensors is usually the basis of IoT-based health monitoring systems. These sensors gather information on a variety of health issues, including physical activity, body temperature, blood pressure, heart rate, and sleep patterns, which can be analyzed and provide real-time monitoring using a smartphone or computer device and then feedback the information gotten to the healthcare providers (3). The cloud platform regularly analyzes patient health data using powerful analytics and machine learning algorithms to spot trends in the users' medical records by enabling smooth health tracking and early detection of future risk that will evolve. According to (4), adequate proactive measures such as real-time monitoring can assist in early detection of health problems before deteriorating and ultimately lead to better overall health outcomes. Early health monitoring can lead to better illness management or bring permanent cure and control. However, this work aims to systematically review the IoT-based health monitoring system through which the following objectives will be met.

i. To determine the most widely adopted model used in IoT-based health monitoring.
ii. To identify the different power sources adopted in the development of IoT.
iii. To provide recommendations from the review for further research.

Literature reviews

Binisha et al. (5) employed sensor devices for recording, communication, and health monitoring of individuals. The study adopted IoT technology as a thin healthcare communication method. The system employed a temperature and heartbeat sensor. These sensors were employed to continuously monitor the patient, and the relevant data were then transmitted to a microcontroller. The microcontroller was then linked to the cloud, where the collected parameters were analyzed. The information is then analyzed, which was connected with the cloud through the Node microcontroller. The results were displayed on an LCD screen to follow-up the patient's health status.

Wu et al. (6) developed a deep learning algorithm-based IoT system for monitoring in real time using portable medical devices. The suggested method measures vital signs using wearable medical devices that use a variety of deep learning algorithms to glean insightful information from the collected data. Even when the doctors are not physically present, these deep learning models assist them in remotely analyzing the athletes' health status and administering the necessary medical interventions needed. Cross-validation tests were carried out thoroughly to assess the suggested performance of the system while taking into consideration several statistically-based performance measures. The results show that the approach works very well for diagnosing serious illnesses in athletes, including heart problems, cancer, and brain tumors.

Chaudhary et al. (7) developed an IoT-based intelligent patient health monitoring system for COVID-19. In case of an emergency, the network of numerous high-accuracy sensors is connected with physicians and caretakers via the internet. To be more precise, the system tracks the patients' health using sensors for heart rate and temperature. The Node MCU ESP8266, which is connected to these sensors, collects data from them and displays it on the LCD and the Wi-Fi connection to interface with an LCD before sending the information to a web server (wireless sensing node). This initiative runs well by utilizing IoT technology, which enables users to periodically check in on the health of their loved ones.

Biradar et al. (8) presented a simple IoT-based health monitoring system with MPU6050, MAX30100 sensors, and Raspberry Pi. The system remotely monitors the patient's important signs, such as heart rate, oxygen saturation, and body movement, and sends these data to a cloud server for further analysis. The MQTT protocol was used by Raspberry Pi to send the processed sensor data to the cloud server after it had been collected and processed. The data are being stored on the cloud server, which can be monitored by medical professionals by allowing medical doctors to provide quicker services and potentially save lives.

Shubhangi et al. (9), using biosensors, created a state-of-the-art healthcare monitoring system that places a premium on exceptional quality and incredibly cheap cost. The study's main goal focuses on how Telemetric & Holter ECG Warehouse (THEW) technology has improved cardiac and ECG monitoring. The authors give a summary of THEW technology's advantage to researchers who are willing to advance heart safety and ECG research.

Raju et al. (10) designed and implemented an Arduino-based eHealth system over the IoT. The system integrates various input modules such as temperature, heart rate, position motion, and humidity monitoring sensors with an output display on the LCD and a buzzer. After analyzing the data, the Arduino-based module uploads it to an Internet of Things that works by continuously monitoring vital indications such as high or low heart rate, elevated body temperature, or patient movement. The device notifies authorized workers through the Internet of Things network. Wearable sensors will be sent to an IoT cloud storage for additional processing, storing, and visualization due to the authors' implementation of a smart IoT gateway that offers data processing, local web server access, and cloud connectivity.

Alruwaili et al. (11) created an IoT-based patient monitoring system that utilizes wearable sensors, smartphones, and wireless data transmission. Body temperature, pulse oximeter, electrocardiograms (ECGs), and heart rate are all monitored by the system remotely. Patient data is saved on a Firebase server for use in a mobile application, and the wireless transfer of information is managed by a microcontroller's Wi-Fi device. The system has a temperature sensor and a specially made pulse sensor to monitor pulse rate precisely. Patients of various ages were used to confirm the suggested model efficiency, and the simulation results demonstrated that the system outperformed commercially available devices and that the BPM readings were similar to those of a heart monitor.

Aggarwal et al. (12) developed a model system that monitors a patient's health parameters and predicts their condition to help prevent future complications. The use of IoT devices and smart notifications for real-time remote health monitoring can detect illnesses, facilitate treatment, and save lives by gathering and analyzing large amounts of data.

Mohammad et al. (13) presented the design and implementation of IoT-based patient monitoring system capable of tracking patients with COVID-19, high blood pressure, and diabetic patients, making use of a microcontroller system. The data were sent to a mobile application via Bluetooth. Users can utilize the IoT-based device to find out their health metrics, which may help them monitor their health over time and seek medical attention as needed. Every measurement related to the patient's health parameters was subjected to a 95% performance with a relative error of 5%.

Islam et al. (14) designed an IoT for early remote monitoring and detection of health-related issues in home settings. The technology made use of three (3) different kinds of sensors, which include the ECG sensor, non-contact infrared sensor, blood oxygen level, and heart rate monitoring. The MQTT transmission protocol was used to transmit the information assembled to the server. Potential diseases are categorized on the server with a pre-trained deep learning model built on a CNN with an attention layer. Should any significant irregularities be identified, the system will immediately link the user to the closest physician for additional diagnostic evaluation. By enabling prompt disease prevention, remote monitoring, and early identification of health-related issue concerns. The combination of deep learning technology and IoT intends to transform the healthcare industry.

Jayachandran et al. (15) present a telemonitoring system device that can be used for a variety of user purposes and is capable of remotely monitoring, assessing, and checking on human health status via the internet for diverse user needs. The remote health monitoring device is an embedded microcontroller system.

Chozhan (16) proposes combining wireless sensor technologies with an IoT-based human monitoring terminal to test health-related indices. The IoT-based human monitoring system, which includes features like precise data gathering, real-time monitoring, alarms, and subject evaluation, appears to be reasonably reliable, according to the test findings. In a short amount of time, this method offers a reliable and scientific foundation for managing and preventing chronic high-risk illnesses.

Pandimadevi et al. (17) developed a health monitoring platform using many sensor networks and IoT. Body temperature, humidity, heart rate, ambient temperature, and fall detection of patients are all continuously been monitored by this system. The ThingSpeak cloud platform receives the measured values of the patient; after that, ThingSpeak scans the data, and if anomalous conditions are found, it will notify the patient's physicians and the responsible family members for those who live in rural locations with limited accessibility to medical services. This solution is very helpful.

Ompal et al. (18) designed an IoT-based patient tracking system that connects to the internet via a microcontroller. The technology monitors the patient's condition and can promptly notify caretakers. The buzzer, which sounds when the sensor outputs change, is then connected to the microcontroller together with other sensors. The sensor data is shown on an LCD screen, making the system easy to set up and capable of providing a rapid response.

Bhardwaj et al. (19) created a robust health monitoring device using IoT technology that can monitor a patient blood pressure, heart rate, temperature, and oxygen level. Through the use of technology, the work aims to enhance patient care by facilitating early diagnosis and treatment. Doctors may quickly access patient information on a display monitor with the suggested system, which is especially helpful in remote places where local clinics can communicate with city hospitals concerning the health problems of their patients.

Ur Rahman et al. (20) developed a method for remote health surveillance that makes use of nearby sensors. In an emergency, the proposed system may send emails to doctors and receive GSM messages. It can also track a user's whereabouts in real time by utilizing artificial intelligence (AI). The system performs feedback functions while a doctor is not present. One such function is an automated injection system that may provide a patient with doses in an emergency. The ECG, SpO_2 level, pulse rate, and body temperature are the main parameters that the device monitors. To process training data in MATLAB and produce output classes with probabilities in comparison to target classes, the researchers employed a deep neural network. Marginal and joint probabilities were used in the construction of the confusion matrix. This system can be beneficial for patients in rural areas, allowing them to monitor vital signs and receive appropriate medical care without the need to visit a hospital, potentially reducing healthcare costs.

Rikibdar et al. (21) developed a personal fitness tracking system that utilizes the Internet of Things to enable patient monitoring outside clinical settings such as at home. This will improve accessibility to healthcare and reduce delivery costs. The approach provides care to patients in their homes by meeting their needs directly. Patients and their loved ones can also find solace in the knowledge that they are being observed and can get assistance if a problem develops. The researchers created a wireless healthcare monitoring system that runs on mobile devices and includes sensors, a data-gathering unit, a microcontroller, and specially written software to offer real-time online information about a patient's physiological status. The device sends data to a website while tracking, displaying, and storing the patient's body temperature and heart rate. All things being considered, the IoT-based patient monitoring system efficiently monitors the patient's medical status and promptly records critical information.

Yadav et al. (22) established an IoT-based health monitoring system using a Raspberry Pi microcontroller. Using a variety of sensors, the system kept an eye on the patient's body temperature, pulse rate, and the temperature and humidity of the room. An Internet of Things dashboard shows the sensor data. Then, utilizing wireless communication, this data were sent to a medical database through an IoT platform so that the authorized medical staff could view this data on their cell phones. The physicians may then make a diagnosis of the patient's and any illnesses based on the values they had received.

Ragupathi et al. (23) presented a portable physiological control panel that could continually monitor the patient's temperature, heart rate, and other vital signs in the room. They proposed an IoT Arduino Uno and remote matching system based on a WiFi module to create a continuous real-time control that keeps track of patient's health condition, which saves patient data in a server. Using any IoT platform, the authorized staff can access the stored data through the suggested health monitoring system, enabling clinicians to diagnose patients based on the values obtained.

Umer et al. (24) build a system that integrates AI and IoT-based technologies for possible medical care solutions. This model was assessed, and its performance was compared with several transfer learning, deep learning, and deep learning methodologies. The IoT technology was used to track and report on the activities of the cardiac patients. To predict cardiac disease, a collective model called ET-CNN was displayed with accuracy of 0.9524. The data from this system were quite encouraging in terms of classifying heart patients with great accuracy and monitoring. Additionally, compared to other models, the suggested method showed good accuracy and less training time.

Abed and Hussein (25) proposed a modified system for monitoring patient health through IoT and provided a 24-hour monitoring device that follows up on patients. Their proposed business plan involved various devices, such as web-based sensor applications that communicate over the network, which makes the system more efficient at monitoring and recording patient health information and medical data. The system they designed has various sensors and monitoring devices that are for collecting medical data from patients for onward transmission via the internet to specialist doctors to enable accurate medical assessment of the patient's health status.

Nosirov et al. (26) developed a multi-parametric real-time human health prediction and monitoring system using methods for tracking and gathering clinical data to identify problems and facilitate quick predictability and awareness. Based on the estimated disease rate, the IoT-based system can notify the patient and their family or immediately contact emergency services. The disease rate can be forecasted on a scale from 0 to 10.

Sahoo et al. (27) designed and developed a heart attack prediction system based on real time and integrated it utilizing web portal technology, ad-hoc networking, vital sign sensors, and position sensors to enable remote patient monitoring and use machine learning techniques to anticipate heart disease. The system utilizes an IoT via an access point and GSM module to warn the user and ensure the effective transfer of vital sign data to a ThingSpeak server cloud. The RBF SVM classifier had the greatest accuracy of 80% according to the data. The significance of this work is that. It combines machine learning and IoT to predict and monitor diseases.

Poorani et al. (28) created a cost-effective, efficient, and sustainable coal mine safety system. The article describes the development of a comprehensive safety system for coal miners that integrates many sensing devices to monitor various critical variables. The system is designed to detect and report on the miner's well-being, including monitoring their vital signs (e.g., depth, stress, temperature, and moisture), detecting hazardous gases, and tracking the miner's location within the mine. An emergency switch is also incorporated to instantly alert authorities in the event of an accident. The system is implemented on a single board, and the data are wirelessly transmitted to a router using an ESP32 Wi-Fi module. An Arduino microcontroller collects the sensor information and communicates it to the Wi-Fi component, which then relays the information to a designated node. This node forwards the data information to a control center for monitoring in real time and appropriate interventions as needed. The researchers emphasize the cost-effectiveness, efficiency, and long-term sustainability of this integrated safety solution for coal mine operations.

Mohammed and Hasan (29), in "IoT-Based Remote Health Monitoring System for Synchronous Patient Supervision," This work proposes an IoT framework for comprehensive health supervision, data recording, storage, visualization, and communication across various domains like healthcare, smart cities, and engineering. The goal of this specific work is to develop an IoT health monitoring system that can monitor important characteristics of a patient and send the data over a network. The system measures blood oxygen level, body temperature, and heart rate using health sensors that are connected to a Raspberry Pi 4B microprocessor. Additionally, a SIM7600E GSM and GNSS HAT module will be used to acquire the patient's location immediately. Next, a network connection sends the sensor data to server cloud storage. Researchers created a cross-platform smartphone application that shows the patient's health state to physicians and patients in real time, facilitating medical decision-making. Healthcare professionals can make prompt and well-informed decisions on the patient's care because of this synchronous monitoring strategy.

Onyan et al. (30) designed and implemented a wireless remote health monitoring device based on IoT to continuously monitor patients' vital signs. The device utilizes a pulse oximeter sensor to measure temperature, heart rate, and blood oxygen saturation by converting these electrical signals that are sent to a NodeMCU for processing from physical quantities. Data are uploaded to the cloud using Google Firebase cloud technology. Implemented the TFT LCD that shows the results, and the integrated Wi-Fi module allows for the timely delivery of medical attention by sending mobile app notifications to the doctor's and caregiver's devices before the vitals fall below predetermined criteria. When the researchers at two different healthcare centers compared the results from the built IoT-based gadget with normal medical equipment, they found that the values were extremely close, indicating the accuracy of the device.

Anan et al. (31) designed and implemented a remote health monitoring system for asthmatic patients based on the IoT using a variety of sensors. The system analyzes and displays data from an electrocardiogram (ECG), heart rate, body temperature, humidity, oxygen saturation (SpO_2), and room temperature in a customized Android application. The system's back end makes use of a web framework based on Python called Django, while the front end was constructed with HTML, CSS, JavaScript, and jQuery. The physician receives the sensor data to keep an eye on the patient's condition and make the necessary recommendations. A microcontroller that was compatible with the AIDE was used to develop the system structure.

Jayakumar et al. (32) put forward an IoT-based healthcare solution that offers continuous wireless patient monitoring. The system comprises of an online mobile application that gathers sensor data, which is subsequently sent by a module attached to a microcontroller to the cloud storage of the IoT platform. The sensors used include an Arduino UNO, MAX30100, EC0567, and AD8232, which are connected to the human body, and the data are displayed on an LCD. The data are processed on the cloud, and a physician can remotely evaluate the processed information to determine what further action has to be taken in response to the data analysis. The caregiver or physician receives an alert message if the patient needs immediate attention.

Kishor and Chakraborty (33) proposed a healthcare model that uses machine learning to reliably and early predict different diseases. They assessed seven different machine learning algorithms: support vector machines, adaptive boosting, decision trees, and Naïve Bayes. Heart disease, diabetes, hepatitis, liver disorders, breast cancer, dermatology, surgical data, heart disease, and thyroid are the nine fatal diseases that can be predicted using forest (RF), artificial neural networks, and K-nearest neighbors. They employed four metrics—accuracy, sensitivity, specificity, and area under the curve—to evaluate the effectiveness of their suggested model. The Random Forest classifier was shown to yield the best results across the various disorders, with an accuracy of 97.62%, a specificity of 97.81%, a sensitivity of 99.67%, and an AUC of 99.32%. The authors concluded that physicians could benefit from early disease diagnosis according to their created healthcare model.

Sahoo et al. (27) developed a real-time IoT-based system for heart attack prediction and health monitoring. Ad hoc networking, web portal technologies, location sensors, and vital signs are all integrated into this system to provide remote health monitoring and heart disease prediction with machine learning techniques. The system ensures efficient transmission of vital sign data to a cloud server and notifies users via a GSM module. The novelty of this work is its combination of machine learning and IoT for disease monitoring and prediction.

Kavitha et al. (34) developed an IoT-based system for tracking/evaluating systemic hypertension before and after therapy. The purpose of this strategy is to reduce the likelihood of hypertension brought on by medication by regularly monitoring vital blood pressure indicators such as temperature, blood pressure, and pulse rate. The IoT device employs sensors such as temperature sensors, blood pressure, and pulse rate to measure temperature, pulse rate, and blood pressure. These sensor devices recognize and analyze the readings, which are subsequently transmitted to a web server for alerting and advice. The effectiveness of the IoT device was evaluated through testing, and precise readings of temperature, blood pressure, and heart rate were measured and sent via an IoT protocol. The application server for the IoT-based HMS for treatment of cancer recommendations and anticipated course of treatment was taken into consideration when processing the values compared to a physical interaction with the patient. The device also offers improved development in patients getting therapy with enhanced accuracy.

Patil et al. (35) developed an intelligent smart health monitoring system with an ATmega328P microcontroller and sensors. The sensors measure heart rate, oxygen saturation, glucose, and blood pressure. The data are shown on a graphic showing a depiction of the human body. After data analysis, the ATmega328P transmits the information to an IoT cloud or the Internet for additional processing. Patient data is transmitted via the internet in a collaborative healthcare setting, which lessens the doctor's workload and produces accurate findings.

Yeri and Shubhangi (36) proposed an IoT-based healthcare application based on continuous wireless patient based continuous monitoring, which comprises a web and mobile application. Sensors are used in measuring the patient's vital signs and data. A doctor can perform a remote analysis of the data once it has been processed in the cloud and feedback measures have been implemented depending on the analysis.

Valsalan et al. (37) developed a portable physiological monitoring framework that constantly monitors patient's vital signs like heartbeat, temperature, and environmental parameters., Including a continuous control mechanism in tracking patient's condition and storing the data information on a server using a Wi-Fi. Based on the received values, doctors can remotely diagnose diseases using IoT.

Tamilselvi et al. (38) introduced an IoT-based healthcare monitoring system for coma patients, also using GSM. Used smart sensors like temperature, heartbeat, eye blink, and SPO_2 to monitor the patient's vital signs by utilizing an Arduino-UNO board as the microcontroller and cloud computing. An accelerometer sensor was used to track the body movement of coma patients, and transmit the patient data to authorized smartphones and laptops via a cloud server, which can be stored and analyzed.

Pandey and Prabha (39) focused on real-time data for accurate prediction and diagnosis using IoT and machine learning. a pulse sensor with Arduino to monitor the pulse with the sensor readings logged in a Google Sheet via IFTTT, which convert the sensor data into a CSV format for further processing. Analyzed the dataset using machine learning algorithms, particularly support vector machine (SVM), which showed high accuracy in predicting heart disease. The proposed hardware and software system can help patients predict heart disease in the early stages.

Mahajan and Birajdar (40) developed a chronic disease monitoring system based on the IoT. The network system is made up of body sensors that gather data from accelerometers, SpO_2, and temperature sensors in real time. As a sensing node, the Particle Photon uses an ARM processor that is built in to process the data before transferring it over WiFi to the cloud. The Adafruit web server can be used to display the data on a dashboard. An MQTT broker/web server mediates between the publisher (the sensors) and subscriber (e.g., a laptop/PC), accepting the sensor data and publishing it for the subscriber to access using a login. The system is important for patients with conditions like osteoporosis, cardiac arrest, and asthma.

Muhammad et al. (41) developed an IoT-enabled fuzzy intelligence system for COVID-19 patients that allows for remote monitoring, diagnosis, and prescription of treatment. An IoT-compatible WiFi module is used by the system to read data from many sensors and send it to a web page for remote access using an Arduino microcontroller. Fuzzy logic is employed to recommend medical treatments based on the patient's condition.

Socrates et al. (42) developed a model for monitoring the respiratory rate of asthma patients. The respiratory rate is calculated using an LM35 temperature sensor, and the frequency value is displayed in a web browser using an Ethernet shield, which is helpful for doctors to access patient information remotely. Data mining techniques are then used to aid in earlier disease detection.

Rafa et al. (43) designed a remote environmental and health monitoring device designed especially for people with asthma who are more vulnerable to COVID-19. The system consists of various sensors that collect data on heart rate, body temperature, ambient temperature, humidity, and air quality. This sensor data is processed through an Arduino microcontroller. Since timely treatment is essential for this high-risk patient population, the system allows in real-time patient information to physicians and medical workers. Via Bluetooth, all the sensor data is sent to a mobile application and updated every few seconds. This makes it possible for medical staff to monitor patients' status and recognize emergencies in real time. Through a comprehensive analysis of all the data gathered, the researchers identified the participants who needed ongoing monitoring because they were especially susceptible to health decline. The remote real-time observation capabilities of this system are designed to improve care delivery and outcomes for asthma patients during a pandemic.

Methodology

Literature research has been carried out from reputable scientific journals and databases with high-quality results. IoT-based health monitoring publications were taken into account. For this review, the publications from 2015 to 2024 were carefully examined. Other researchers have adopted a methodology based on real-time monitoring only. However, this review considers a methodology that explores all the fields of IoT and explores the advantage of other artificial intelligence techniques that will be useful in health monitoring and predicting of future occurrence of disease. This method was adopted because it gives a broad overview of the different methods adopted in the field of IoT in relation to different works. The result was reached by extracting the relevant information in the field of IoT health monitoring. A tabular chart has been used to obtain the different methodology adopted in the field of IoT.

Discussion

As presented in **Table 1** and from the foregone survey, the most widely used method of health monitoring appears to be the use of IoT as given by serial no (2, 4, 5, 6, 7, 8, 9, 11, 13, 15, 16, 17, 19, 20, 21, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 35, 36, 37, 38, and 40), followed by the use of Deep Learning and IoT with serial no (3, 12, and 14). Followed by Convolutional Neural Network with serial no (10 and 41), Machine Learning and IoT with serial no (30 and 34). The popular list includes SVM, Fuzzy, and IoT-based and convolutional neural networks with serial numbers (39, 1, and 41), respectively. From the literature review, the use of IoT was found to be the most widely used method in health monitoring systems. Some of the work considers the use of fuzzy logic with IoT, but none of the work considers the use of ANFIS and ANN with IoT not only in monitoring but also in predicting modeling techniques, which will enhance the systems' ability to provide early

TABLE 1 | Systematic review of IoT-based health monitoring system.

S/n	Authors name and year	Method
1.	Muhammad et al. (41)	FUZZY + IoT-based
2.	Binisha et al. (5)	IoT-based
3.	Wu et al. (6)	DL + IoT-based
4.	Chaudhary et al. (7)	IoT-based
5.	Biradar et al. (8)	IoT-based
6.	Shubhangi et al. (9)	IoT-based
7.	Raju et al. (10)	IoT-based
8.	Alruwaili et al. (11)	IoT-based
9.	Aggarwal et al. (12)	IoT-based
10.	Islam et al. (14)	CNN + IoT-based
11.	Jayachandran et al. (15)	IoT-based
12.	Umer et al. (24)	DLM + IoT-based
13.	Poorani et al. (28)	IoT-based
14.	Sobia et al. (44)	DL + IoT-based
15.	Mohammed and Hasan (29)	IoT-based
16.	Onyan et al. (30)	IoT-based
17.	Kavitha et al. (34)	IoT-based
18.	Mohammad et al. (13)	IoT-based
19.	Chozhan (16)	IoT-based
20.	Pandimadevi et al. (17)	IoT-based
21.	Ompal et al. (18)	IoT-based
22.	Bhardwaj et al. (19)	IoT-based
23.	Rikibdar et al. (21)	IoT-based
24.	Yadav et al. (22)	IoT-based
25.	Ragupathi et al. (23)	IoT-based
26.	Nosirov et al. (26)	IoT-based
27.	Bhardwaj et al. (19)	IoT-based
28.	Rafa et al. (43)	IoT-based
29.	Abed and Hussein (25)	IoT-based
30.	Sahoo et al. (27)	ML+ IoT-based
31.	Anan et al. (31)	IoT-based
32.	Jayakumar et al. (32)	IoT-based
33.	Socrates et al. (42)	IoT-based
34.	Kishor and Chakraborty (33)	ML + IoT-based
35.	Patil et al. (35)	IoT-based
36.	Yeri and Shubhangi (36)	IoT-based
37.	Valsalan et al. (37)	IoT-based
38.	Tamilselvi et al. (38)	IoT-based
39.	Pandey and Prabha (39)	SVM + IoT-based
40.	Mahajan and Birajdar (40)	IoT-based
41.	Bhat et al. (45)	CNN + IoT based

KEY: IoT: Internet of Things. CNN: Convolutional Neural Network. DL: Deep Learning. DLM: Deep Learning Machine. ML: Machine Learning. ANN: Artificial Neural Network. AI: Artificial Intelligence. SVM: Support Vector Machine.

disease detection, personalized health recommendations, and proactive intervention for future occurrences of health issues. Most of the work used a DC battery as the source of power to the system; none of the work reviewed use or considered the used of solar power as an alternative source of power for constant and effective patient monitoring.

In addressing these key research gaps, future studies can contribute to the development of more advanced, comprehensive, and effective IoT-based health monitoring solutions that can positively impact patient care, especially in underserved regions with limited or no access to traditional medical facilities.

Conclusion

An extensive summary of the state of review and development in the field of IoT-powered health monitoring systems has been made possible by this systematic review. The review shows that the use of IoT is the most widely adopted method, followed by CNN, ML, SVM, and Fuzzy logic with IoT, respectively. The paper therefore recommended the use of other Artificial Intelligent such as ANN and ANFIS with IoT for monitoring and predicting future occurrences of possible health issues most, especially for people living in rural areas where health care has been a major challenge with low budget, and less technological know-how. Also, the use of solar power as a hybrid alternative source of power for effective monitoring should also be considered especially for people living in rural areas.

Acknowledgments

We acknowledge Pius C. Sarmeje and David T. Ogbaka for their help in arranging the manuscript and the Directorate of ICT, Adamawa State University, Mubi, for the provision of network service and constant power supply. The authors, however, acknowledge the reviewers and editors for their sacrifice in providing valuable comments and suggestions.

Conflicts of interest

The authors declare that the review was conducted in the absence of any commercial or financial relationship that could be constructed as a potential conflicts of interest.

Authors contribution

This work was carried out in collaboration between the two authors. KGG designed the study, developed the IoT-based health monitoring, and produced the first draft of the manuscript. AD managed the literature searches and proofread the manuscript before all authors approved the final manuscript.

Funding sources

The authors would wish to declare that no funding source is associated to the work.

References

1. Ali Z, Hossain MS, Muhammad G, Sangaiah AK. An intelligent healthcare system for detection and classification to discriminate vocal fold disorders. *Future Gener Comput Syst*. (2018) (85):19–28.
2. Khan WZ, Aalsalem MY, Khan MK, Arshad Q, Alam M. A reliable Internet of Things-based architecture for the oil and gas industry. *2019 International Conference on Computer, Control, Electrical, and Electronics Engineering (IEEE)*. (2019). p. 1–6. doi: 10.1109/ICCCEEE46830.2019.9071561
3. Chuah MC, Fu F. ECG anomaly detection via time series analysis. *Proceedings of the Frontiers of High-Performance Computing and Networking ISPA 2007 Workshops: ISPA 2007 International Workshops SSDSN, UPWN, WISH, SGC, ParDMCom, HiPCoMB, and IST-AWSN Niagara Falls, Canada, 28 August–1 September 2007 Proceedings 5*. Berlin/Heidelberg: Springer (2007). p. 123–35.
4. Baig MM, Gholamhosseini H, Connolly MJ. A comprehensive survey of wearable and wireless ECG monitoring systems for older adults. *Med Biol Eng Comput.* (2013) 51(5):485–95. doi: 10.1007/s11517-012-1021-6
5. Binisha XM, Archana Devi S, Binisha Rose J. IoT based human health care monitoring system using UBS method. *Int Res J Mod Eng Technol Sci.* (2023) 5(3).
6. Wu X, Liu C, Wang L, Bilal M. Internet of things-enabled real-time health monitoring system using deep learning. *Neural Comput Appl.* (2023) (35):14565–76.
7. Chaudhary A, Kavale G, Chavan O, Gawari AA. A survey on IoT based patient monitoring system. *Int J Res Public Rev.* (2023) 4(5): 3245–9.
8. Biradar S, Khose R, Rudraksha A, Narute G. IoT based healthcare system: a review. *Int J Progress Res Sci Eng.* (2023) 4(5):100–4.
9. Shubhangi DC, Gadgay B, Ansari NS, Waheed MA. IoT based healthcare system: a review based health-care monitoring system. *Int J Res Public Rev.* (2023) 4(1):983–6.
10. Raju K, Dhana Lakshmi N, Durga Komal PVNSS, Sri Hari B, Harika Devi S. IoT based healthcare system: a review based ICU patient monitoring system. *J Eng Sci.* (2023) 14(4.2):34–41.
11. Alruwaili M, Hameed Siddiqi M, Farid K, Azad M, Alanazi S, Khan A, et al. A health monitoring system using IoT-based android mobile application. *Comput Syst Sci Eng.* (2023) 47(2):2294–311.
12. Aggarwal A, Pandey A, Singh A, Srivastava D, Choudhary I. IoT based health monitoring system. *J Curr Res Eng Sci.* (2023) 6(1):1–12. Paper 41. Appl Math Sci. (2012) 6(63):3133.
13. Muhammad ZUR, Ali HR, Abeer AA, Muhammad AA, Rabia L, Muhammad TR, et al. Real-time artificial intelligence-based health monitoring, diagnosing and environmental control system for COVID-19 patients. *J Math Biosci Eng.* (2022) 8(19):7586–605.
14. Islam MR, Kabir MM, Mridha MF, Alfarhood S, Safran M, Che D. Deep learning-based IoT system for remote monitoring and early detection of health issues in real-time. *Sensors.* (2023):1–18.
15. Jayachandran S, Ghodsi M, Zaheri MM. Development of a miniature and low-cost IoT-based remote health monitoring device. *World Acad Sci Eng Technol Int J Biomed Biol Eng.* (2023) 17(10): 245–50.
16. Chozhan V. An IoT based healthcare system: a review based health monitoring system (ECG, temperature, heartbeat, skin & SpO_2). *Int J Res Eng Technol.* (2022) 10(6):43–52.
17. Ganesan P, Hameed T, Maruthakutti M, Vairamuthu S. Design of IOT based health monitoring system. *Saudi J Eng Technol.* (2022) 7(11): 585–92.
18. Ompal E, Gupta SR, Pal AK, Shukla M, Kumar A. IoT based healthcare system: a review based patient health monitoring system. *Int J Res Public Rev.* (2022) 3(5):1262–71.
19. Bhardwaj V, Joshi R, Gaur AM. IoT-based smart health monitoring system for COVID-19. *Spring Nat J.* (2022):136–7.
20. Ur Rahman MZ, Raza AH, AlSanad AA, Akbar MA, Liaquat R, Riaz MT, et al. Real-time artificial intelligence-based health monitoring, diagnosing and environmental control system for COVID-19 patients. *J Math Biosci Eng.* (2022) 19(8):7586–605.
21. Rikibdar SV, Sawant PR, Shingade PS, Kamble V. IoT based healthcare system: a review-based health monitoring system. *Int Res J Eng Technol.* (2022) 9(6):3282–5.
22. Yadav M, Vardhan A, Chauhan AS, Saini S. IoT based health monitoring system. *Int J Creat Res Thoughts.* (2022) 10(1):708–15.
23. Ragupathi T, Kumar AN, Prasanna S. Health monitoring system based on IoT. *Int J Health Sci.* (2022) 6(S2):9902–9.
24. Umer M, Aljrees T, Karamti H, Ishaq A, Alsubai S, Omar M, et al. Heart failure patients monitoring using IoT based remote monitoring system. *Sci Rep*. (2023) 13(19213):1–19.
25. Abed NJ, Hussein EA. Design and implementation of real-time healthcare monitoring system based on IoT. *J Phys Conf Ser.* (2021):1–9.
26. Nosirov K, Begmatov S, Arabboev M. https://www.researchgate.net/publication/343653377. (2022).
27. Sahoo S, Borthakur P, Baruah N, Chutia BP. IoT and machine learning-based health monitoring and heart attack prediction system. *J Phys Conf Ser.* (2021) 1950(1):012056. doi: 10.1088/1742-6596/1950/1/012056
28. Poorani G, Srivignesh P, Roshan Karthick K, Krishnan S. Health monitoring system using IoT based sensors. *ECB J.* (2023):7966–74.
29. Mohammed BG, Hasan DS. Smart healthcare monitoring system using IoT. *IJIM.* (2023) 17(1):141–52.
30. Onyan AO, Onyishi DU, Ebireri TA, Onawharaye R. Development of an IoT based wireless remote health monitoring device. *FUPRE J Sci Ind Res.* (2023) 7(3):79–92.
31. Anan SR, Hossain MA, Milky MZ, Khan MM, Masud M, Aljahdali S. Research and development of an IoT-based remote asthma patient monitoring system. *J Healthcare Eng.* (2021) 2021:1–21.
32. Jayakumar S, Ranjith Kumar R, Tejswini R, Kavil S. IoT-based health monitoring system. *Advances in Parallel Computing Technologies and Applications*. IOS Press (2021). p. 193–200.
33. Kishor A, Chakraborty C. Artificial intelligence and internet of things-based healthcare 4.0 monitoring system. *Wirel Pers Commun.* (2021) 127(2):1615–31. doi: 10.1007/s11277-021-08708-5
34. Kavitha S, Sheikh SM, Ngebani I, Matlotse E. An IoT based health monitoring system for cancer treatment. *J Health Technol.* (2023) 7:1–7.
35. Patil P, Patil S, Parab G, Salvi M, Nair A. IoT based patient health monitoring system. *In J Eng Res Technol.* (2021) 9(3):716–9.
36. Yeri V, Shubhangi DC. IoT based real time health monitoring. *Proceedings of the Second International Conference on Inventive Research in Computing Applications (ICIRCA)*. (2020). p. 980–4.
37. Valsalan P, Baomar TAB, Baabood AHO. IoT based health monitoring system. *J Crit Rev.* (2020) 7(4):739–43.
38. Tamilselvi V, Sribalaji S, Vigneshwaran P, Vinu P, Ramani JG. IoT based healthcare system: a review based health monitoring system. *IEEE.* (2020):386–9.
39. Pandey H, Prabha S. Smart health monitoring system using IoT and machine learning techniques. *Appl Math Sci.* (2020) 5(41):2039–48.
40. Mahajan S, Birajdar AM. IoT-based healthcare system: a review based smart health monitoring system for chronic diseases. *IEEE Xplore.* (2019):1–5.
41. Ur Rahman MZ, Akbar MA, Leiva V, Martin-Barreiro C, Imran M, Riaz MT. An IoT-fuzzy intelligent approach for holistic management of COVID-19 patients. *Heliyon*. (2024) 10(1):e22454.

42. Socrates TP, Socrates TP, Azki M, Azrianto A, Jihadi MF. Asthma monitoring: respiratory monitoring system for asthma patients based on the internet of things. *IJEBIIITS.* (2021) 1(2):5–13.
43. Rafa NS, Azmal BB, Dhruba AR, Khan MM, Alanazi TM, Almalki FA, et al. IoT-based remote health monitoring system employing smart sensors for asthma patients during COVID-19 pandemic. *Wireless Communications and Mobile Computing.* (2022). p. 1–14.
44. Wassan S, Dongyan H, Suhail B, Jhanjhi NZ, Xiao G, Ahmed S. Deep convolutional neural network and IoT technology for healthcare. *Digit Health.* (2023) (9):1–21.
45. Bhat GS, Shankar N, Kim D, Song DJ, Seo S, Panahi IM, et al. Machine learning-based asthma risk prediction using IoT and smartphone applications. *IEEE Trans J.* (2016) 4: 1–7.