

Advancing Healthcare With ML And Iot: Predictive Models For Chronic Disease Prevention: A Review

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Chronic diseases have emerged as a major global public health concern, with their incidence increasing at an alarming rate. Early detection and prevention of these conditions not only improves patient outcomes but also reduces healthcare costs. Leveraging the synergy between Machine Learning (ML) and the Internet of Things (IoT) has enormous potential to revolutionize healthcare, notably through predictive modelling for chronic illness risk assessment. This analysis digs into the challenges and potential involved in developing a prediction model for chronic disease using ML and IoT. It provides a complete overview of current research status and outlines critical routes for future inquiry, addressing topics such as data protection, algorithm refining, and seamless interaction with electronic health records. Furthermore, the significance of wearable gadgets and remote monitoring in forecasting chronic diseases is investigated, as is the possibility of precision medicine for tailored risk assessment. This paper emphasizes the significance of interdisciplinary collaboration and standardization in enabling the effective deployment of ML and IoT-based solutions for chronic disease prediction.

Key Words: Chronic disease, Machine learning, Internet of Things (IoT), Medical diagnosis.

1 INTRODUCTION

Chronic diseases are a major global health challenge, affecting millions of people worldwide. According to the World Health Organization (WHO), chronic diseases account for an estimated 71% of all deaths globally, with cardiovascular diseases, cancer, chronic respiratory diseases, and diabetes being the leading causes (Organization & others, 2018). In addition to their impact on mortality, chronic diseases can significantly impact the quality of life and productivity of patients, as well as placing a substantial burden on healthcare systems (Bloom et al., 2012).

Early detection and prevention of chronic diseases are critical to improving patient outcomes and reducing healthcare costs. However, traditional approaches to chronic disease

management, which rely on periodic check-ups and symptom management, are often reactive and not effective at identifying patients at high risk of developing chronic diseases (Smith et al., 2016). Predictive modeling, which uses data to identify individuals who are at high risk of developing chronic diseases, can enable more effective and personalized interventions (Obermeyer & Emanuel, 2016).

Machine learning (ML) and the Internet of Things (IoT) are two technologies that have the potential to transform healthcare by enabling predictive modeling for chronic disease risk assessment. ML algorithms can analyze large datasets to identify patterns and predict outcomes, while IoT devices can collect data on various aspects of patients' health and behavior, such as physical activity, sleep patterns, and vital signs. The combination of ML and IoT can enable the development of predictive models for chronic disease risk assessment that can be used to identify high-risk patients and provide targeted interventions (Rahman et al., 2020; Sharma & Joshi, 2021).

Despite the potential benefits of ML and IoT-based solutions for chronic disease prediction, there are several challenges that must be addressed to enable their effective implementation. One major challenge is data privacy and security, as the collection and analysis of sensitive health data raise ethical and legal concerns (S. Li et al., 2018). Another challenge is algorithm development, as the accuracy and generalizability of ML algorithms depend on the quality and representativeness of the training data. Integration with electronic health records (EHR) is another important consideration, as predictive models need to be integrated into clinical workflows to be effective (Alloghani et al., 2020). Standardization of data collection and analysis is also crucial, as variations in data collection methods and data quality can affect the accuracy and validity of predictive models (Zonta et al., 2020).

In addition, the role of wearable devices and remote monitoring in chronic disease prediction is still being explored. Wearable devices, such as smartwatches and fitness trackers, can provide real-time data on patients' physical activity, heart rate, and sleep patterns, which can be used to inform predictive models (Patel et al., 2012). Remote monitoring, which enables patients to monitor their health at home and receive feedback from healthcare providers, can also improve the accuracy and timeliness of chronic disease prediction (Steinhubl et al., 2015).

Precision medicine, which aims to provide personalized and targeted interventions based on patients' genetic, environmental, and lifestyle factors, has the potential to revolutionize chronic disease prediction and prevention. However, the integration of precision medicine with ML and IoT-based solutions is still in its early stages, and further research is needed to understand its potential and limitations (Torkamani et al., 2017).

This review paper aims to provide a comprehensive analysis of the challenges and opportunities in developing a model for chronic disease prediction using ML and IoT. We will analyze the current state of research and identify key areas for future research to enable the effective implementation of ML and IoT-based solutions for chronic disease prediction. We will also discuss the potential impact of these solutions on patient outcomes, healthcare costs, and population health. By providing a critical analysis of the current state of research and identifying key areas for future research, this review paper aims to contribute to the development of effective and sustainable solutions for chronic disease prediction and prevention. The flowchart of the study is presented in **Fig. 1**.

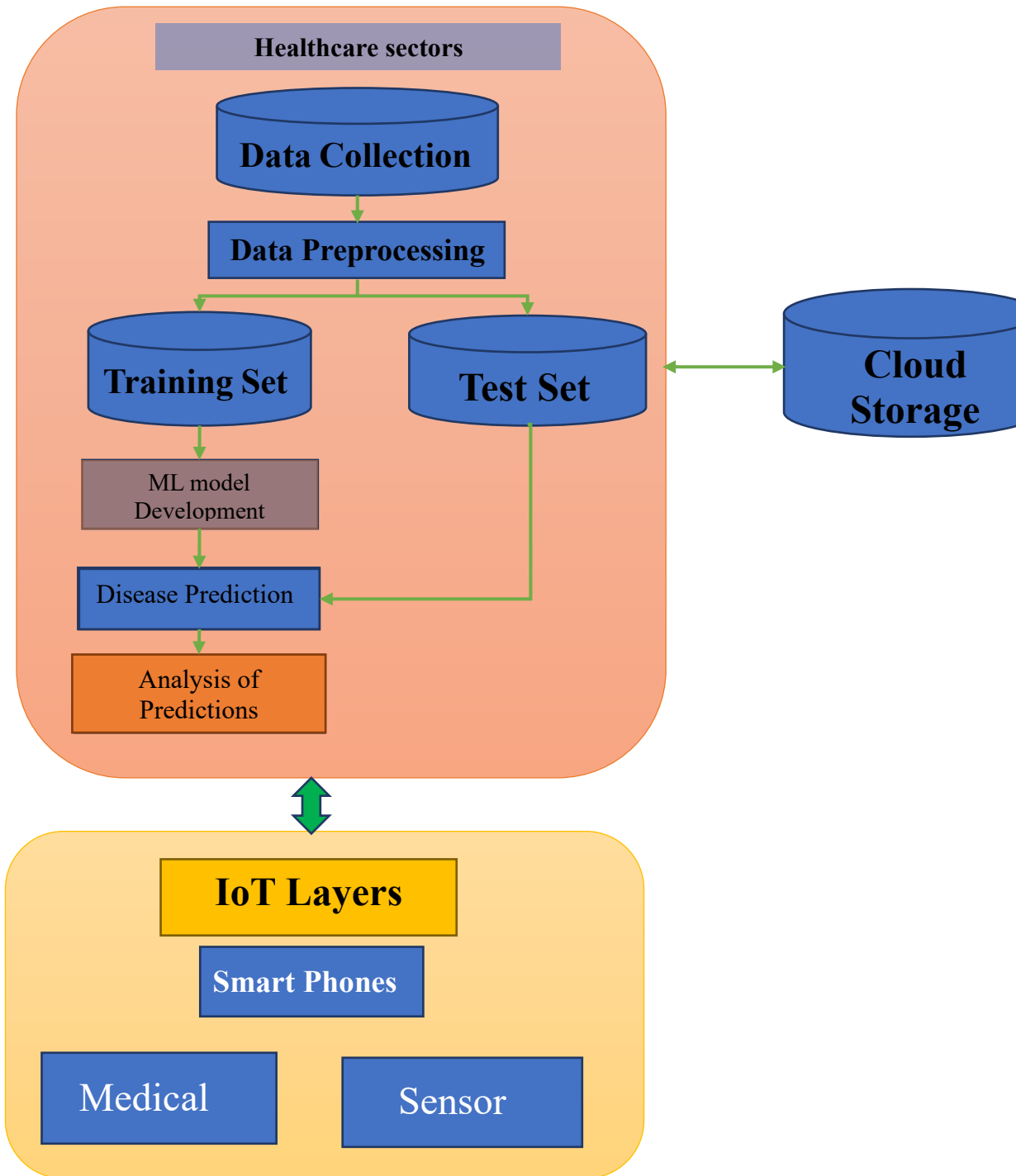


Fig. 1Flowchart of the study.

The main contribution of this review paper is to provide a comprehensive analysis of the challenges and opportunities in developing a model for chronic disease prediction using machine learning and IoT. Specifically, the paper aims to:

- Identify the current state of research in the field of chronic disease prediction using machine learning and IoT, including the types of chronic diseases studied, the types of data used, and the accuracy of existing models.
- Analyze the key challenges and opportunities in developing effective and sustainable solutions for chronic disease prediction using machine learning and IoT, including data privacy and security, algorithm development, integration with electronic health records, and standardization of data collection and analysis (Suman2023).
- Highlight the potential impact of machine learning and IoT-based solutions on patient outcomes, healthcare costs, and population health.
- Identify key areas for future research in the field of chronic disease prediction using machine learning and IoT, including the role of wearable devices and remote monitoring, the integration of precision medicine, and the need for interdisciplinary collaboration.

By providing a critical analysis of the current state of research and identifying key areas for future research, this review paper aims to contribute to the development of effective and sustainable solutions for chronic disease prediction and prevention. The paper's insights and recommendations may be valuable to researchers, healthcare professionals, policymakers, and other stakeholders involved in the development and implementation of machine learning and IoT-based solutions for chronic disease prediction.

The organization of the studies is shown in **Fig. 2**:

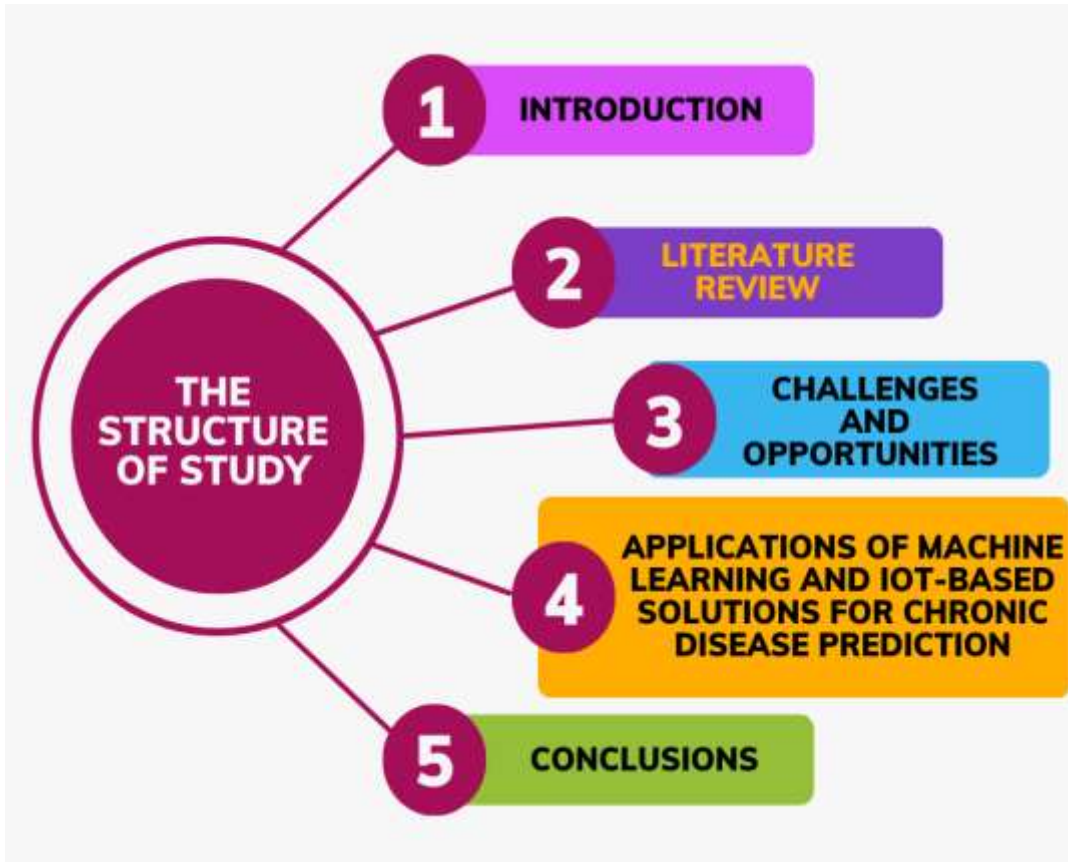


Fig. 2 The structure of the study.

2 LITERATURE REVIEW

2.1 CURRENT STATE OF RESEARCH IN CHRONIC DISEASE PREDICTION USING MACHINE LEARNING AND IOT

The field of chronic disease prediction using machine learning and IoT is rapidly evolving, with numerous studies exploring the potential of these technologies to improve patient outcomes and reduce healthcare costs. Current research in this area focuses on the development and validation of predictive models for a range of chronic diseases, including cardiovascular disease, diabetes, chronic obstructive pulmonary disease, and cancer (Alaa et al., 2019; Jiang et al., 2017).

Recent studies have demonstrated the potential of machine learning algorithms in analyzing complex and heterogeneous data sets to identify patients at high risk of chronic disease. These data sets include electronic health records, medical imaging, genetic data, social determinants of health, and patient-generated data from wearables and other IoT devices. Machine learning techniques such as artificial neural networks, decision trees, and support

vector machines are commonly used to develop these predictive models(Kourou et al., 2015; Liang et al., 2019).

Several studies have also explored the potential of IoT-based solutions for remote monitoring and management of chronic diseases, such as the use of wearable devices for real-time monitoring of vital signs and physiological parameters. These solutions can help to identify early signs of disease progression and provide personalized interventions and treatment recommendations(Steinhubl et al., 2015).

While there have been promising results in the development of predictive models for chronic disease using machine learning and IoT, there are still significant challenges that need to be addressed. These include data privacy and security, algorithm development, integration with electronic health records, and standardization of data collection and analysis. Addressing these challenges will be critical to the successful development and implementation of machine learning and IoT-based solutions for chronic disease prediction(Fang et al., 2016; Kostkova et al., 2016; Torous& Roberts, 2017).

2.2 TYPES OF CHRONIC DISEASES STUDIED, AND TYPES OF DATA USED

A wide range of chronic diseases have been studied using machine learning and IoT-based solutions for prediction and prevention. These includes:

- **Cardiovascular disease:** Studies have focused on predicting outcomes such as heart attack, stroke, and hypertension. Data used includes electronic health records, medical imaging, genetic data, and patient-generated data from wearable devices(Krittanawong et al., 2017).
- **Diabetes:** Machine learning models have been developed to predict the risk of developing diabetes, as well as to predict complications such as retinopathy and neuropathy. Data used includes electronic health records, medical imaging, genetic data, and patient-generated data from glucose monitors and other IoT devices(Dagliati et al., 2018).
- **Chronic obstructive pulmonary disease (COPD):** Studies have focused on predicting the severity of COPD, as well as exacerbations and hospitalizations. Data used includes electronic health records, medical imaging, and patient-generated data from spirometers and other IoT devices(Rahmani et al., 2018).
- **Cancer:** Machine learning models have been developed to predict the risk of developing various types of cancer, as well as to predict prognosis and response to treatment. Data used includes electronic health records, medical imaging, genetic data, and patient-generated data from wearable devices(Liu et al., 2019).

The types of data used in these studies vary depending on the specific disease and the research question being addressed. Electronic health records provide a rich source of data on patients' medical history, including diagnoses, medications, and laboratory results. Medical imaging can provide additional information on the structure and function of organs and tissues. Genetic data can help identify patients at high risk of developing certain

diseases, while patient-generated data from IoT devices can provide real-time information on patients' physiological parameters, activity levels, and environmental exposures.

Overall, the use of diverse types of data is a strength of machine learning and IoT-based solutions for chronic disease prediction, as it allows for a more comprehensive and personalized approach to healthcare. However, challenges remain in integrating and analyzing these disparate data sources, which must be addressed to fully realize the potential of these technologies. **Table 1** summarizes the similar study done by using different ML models and diseases by various researchers.

Table 1Summary of the similar study

Researcher(s)	ML Model	Disease Targeted	Key Findings	Advantages	Limitations
(Prakoso et al., 2023)	Random Forest	Heart Disease	Most popular ML algorithm for heart disease prediction.	Effective in existing studies.	Requires larger datasets for improved accuracy.
(Ullah et al., 2023)	Various ML algorithms	Heart Disease	Reviewed for clinical decision support systems in heart disease diagnosis.	Comprehensive analysis of algorithms.	Specific algorithm effectiveness not detailed.
(Salcedo et al., 2022)	ML and AI	Thoracic Aortic Diseases	Focus on data analysis methods and predicting complications.	Modern approaches in treatment planning.	Broad focus, may lack disease-specific insights.
(Singh & Kaushik, 2023)	ML and deep-learning	Anticancer Drug Response	Highlighted as consistent and effectual for prognosis.	High consistency and effectiveness.	Requires validation in prospective studies.
(Cabrera et al., 2022)	ML techniques	Dengue Fever	Emphasized the need for effective predictors in	Useful in understanding epidemiological patterns.	More large-scale studies needed for validation.

			epidemiolog y.		
(Ghasiya& Okamura, 2021)	Decision Tree, Random Forest, Adaboost	COVID- 19	Explored for predicting infection rates with varying accuracies.	Varied approaches offer comprehensiv e insights.	Accuracy ranges need improvement.
(Malik et al., 2022)	Convolution al Neural Networks	Leukemi a	Show promise in improving disease detection using large datasets.	Leverages large datasets for improved outcomes.	Requires high-quality, large-scale image data.
(Kaur et al., 2019)	Decision tree-based Random Forest, SVM	Diabetes	Achieved an accuracy score of 83%.	High accuracy in prediction.	Specificity to the dataset may limit generalization.
(Javeed et al., 2023)	Image-based ML models	Dementia	Identified as promising compared to clinical features and voice data models.	Shows promise in early detection.	Comparative effectiveness with other data not clear.
(Khalid et al., 2023)	Hybrid model (various classifiers)	Chronic Kidney Disease	Achieved 100% accuracy on the dataset.	Demonstrates effectiveness of hybrid approach.	May not generalize to other datasets or conditions.

2.3 ACCURACY OF EXISTING MODELS

The realm of chronic disease diagnosis has been significantly enhanced by the integration of Artificial Intelligence (AI) and Machine Learning (ML) methodologies. Various researches have demonstrated the effectiveness of different ML models in accurately predicting chronic diseases. This section consolidates the accuracy of existing models based on the findings from recent studies.

Attention-Based Customized CNN Model: The study by Tareq et al., (Tareq et al., 2023a), employed an attention-based customized Convolutional Neural Network (CNN) model that achieved a validation accuracy of 92.67%, showcasing high efficacy in predicting COVID-19, viral pneumonia, and normal healthy cases with individual F1 scores of 91%, 97%, and 90%, respectively. This model, leveraging pathology reports and chest X-ray images, presents a promising tool for the diagnosis of various chronic conditions including diabetes, cardiac disorders, liver diseases, and chronic kidney diseases.

IoMT and ML Hybrid Approach: Natasha Nigar et al., (Nigar et al., 2023a), proposed an Internet of Medical Things (IoMT) and ML-based hybrid system for diagnosing six different chronic diseases. Their comparative analysis of multiple ML models highlighted significant variations in accuracy, precision, recall, F1 score, and area under the curve (AUC), emphasizing the potential of combining IoT with ML for enhancing early detection and monitoring of chronic diseases.

Decision Tree-Based Chronic Diseases Detection Model: In the research by Abhinava Kumar Srivastava et al., (Srivastava et al., 2023), a decision tree algorithm was utilized within a Multiple Disease Prediction System, predicting heart disease, diabetes, and breast cancer with remarkable accuracies of 97.98%, 92.62%, and 91.55% respectively. The study underscores the model's superiority in predictive accuracy compared to traditional models, offering a user-friendly and efficient tool for early disease detection.

Evaluation of ML Algorithms: Ivan Jovović et al., (Jovovic et al., 2023), explored the efficacy of three ML algorithms—Random Forest, Support Vector Machines, and Naive Bayes. The Random Forest algorithm outshined others, delivering the best performance with an average accuracy rate of 87%, which further improved to 90% upon additional tuning. This finding accentuates the importance of algorithm selection and optimization in achieving high predictive accuracy in disease diagnosis.

These studies collectively underscore the significant strides made in the application of ML models for chronic disease prediction. The reported accuracies reflect the models' capabilities in processing complex datasets to deliver reliable diagnostic predictions, hence contributing profoundly to preemptive healthcare measures. The advancements underscored in these works highlight the ongoing evolution in medical diagnostics, promising enhanced predictive accuracy, early detection, and personalized healthcare solutions.

2.4 KEY FINDINGS FROM PREVIOUS STUDIES

The section synthesizes the crucial insights derived from prior research on chronic disease prediction using ML and IoT technologies. These studies collectively highlight the potential of ML and IoT to revolutionize healthcare by enabling early detection, continuous monitoring, and personalized treatment strategies for chronic conditions. Key findings emphasize the accuracy, efficiency, and predictive power of these technologies, underscoring their role in enhancing patient outcomes, optimizing healthcare delivery, and facilitating proactive health management (suman et al 2024). The integration of ML algorithms with IoT devices has been particularly noted for its capacity to transform data

into actionable insights, thereby supporting informed clinical decisions and promoting a preventative healthcare model, several key findings have been found, as shown in **Table 2**:

Table 2. Studiessummary table of the key findings

Ref	Title	Key Finding
(Nigar et al., 2023b)	IoMT Meets Machine Learning: From Edge to Cloud Chronic Diseases Diagnosis System	Demonstrates the efficacy of integrating IoMT with ML for real-time chronic disease monitoring and diagnosis.
(Rajalakshmi et al., 2023)	Prediction of Chronic Heart Disease using Machine Learning	Focuses on ML algorithms' predictive accuracy in diagnosing chronic heart diseases, highlighting the potential for early intervention.
(Korke et al., 2022)	Chronic Disease Prediction Using Machine Learning	Evaluates various ML models' capabilities in predicting chronic diseases, emphasizing the importance of accurate models for healthcare.
(Tareq et al., 2023b)	Evaluation of Artificial Intelligence-Based Models for the Diagnosis of Chronic Diseases	Assesses AI models' diagnostic performance, suggesting significant potential in chronic disease management.
(Xie et al., 2022)	Care for the Mind Amid Chronic Diseases: An Interpretable AI Approach Using IoT	Explores an interpretable AI model using IoT for mental health care in chronic disease patients, indicating broader applicability.

3 CHALLENGES AND OPPORTUNITIES IN DEVELOPING A MODEL FOR CHRONIC DISEASE PREDICTION USING MACHINE LEARNING AND IOT

Chronic diseases are one of the leading causes of death and disability worldwide. According to the World Health Organization (WHO), chronic diseases account for 71% of all deaths globally(Organization & others, 2022). The economic burden of chronic diseases is also significant, with healthcare spending on chronic diseases accounting for a substantial portion of total healthcare expenditure in many countries.

MLis a powerful tool for predicting the risk of chronic diseases, and the use of ML in healthcare has increased significantly in recent years. ML algorithms can analyze large datasets and identify patterns that can be used to predict disease risk, allowing for early detection and prevention of chronic diseases.

One of the key challenges in developing ML-based models for chronic disease prediction is data quality and quantity(Obermeyer & Emanuel, 2016). ML algorithms require large and diverse datasets to achieve high accuracy, and obtaining such datasets can be challenging in

the case of chronic diseases. Electronic health records (EHRs) are one source of data that can be used for chronic disease prediction, but EHR data can be incomplete or inconsistent, making it difficult to train accurate ML models(Rajkomar et al., 2018).

IoT-based technologies provide another source of data that can be used for chronic disease prediction. Wearable devices, such as smartwatches and fitness trackers, can collect a wide range of health-related data, including heart rate, sleep patterns, and physical activity(Piwek et al., 2016). The use of IoT-generated data for chronic disease prediction is still in its early stages, but several studies have shown promising results.

For example, a study published in the Journal of Medical Internet Research used data from a wearable device to develop a machine learning model for predicting the risk of developing type 2 diabetes. The model achieved an accuracy of 92.6%, demonstrating the potential of IoT-generated data for chronic disease prediction(X. Li et al., 2017).

However, the use of IoT-generated data for chronic disease prediction also presents challenges. Data integration can be difficult, as IoT-generated data can be highly heterogeneous, and different types of data may need to be combined to achieve accurate predictions. Interpretability is also a challenge, as ML models can be highly complex and difficult to understand. This is particularly important in the case of chronic disease prediction, as clinicians need to be able to interpret the predictions and take appropriate actions(Kourou et al., 2015).

Data privacy and security is another challenge associated with the use of IoT-generated data(Kourou et al., 2015). Patient-generated data from IoT devices is highly sensitive, and ensuring the secure handling and storage of this data is critical to protecting patient privacy(Islam et al., 2015).

Despite these challenges, the use of ML-based models for chronic disease prediction using IoT-generated data provides several opportunities. For example, ML models can be tailored to individual patient needs, allowing for personalized medicine. The use of real-time monitoring provided by IoT devices can also allow for the development of predictive models that can adapt to changes in patient health status.

Early detection and prevention are also potential benefits of ML-based models for chronic disease prediction. By identifying patients at high risk of developing chronic diseases, healthcare providers can intervene early to prevent or delay disease progression, leading to improved patient outcomes and reduced healthcare costs.

In conclusion, the use of ML-based models for chronic disease prediction using IoT-generated data provides both challenges and opportunities. Data quality and integration, interpretability, and data privacy and security are key challenges that need to be addressed. However, the potential benefits of ML-based models, including personalized medicine, early detection, and real-time monitoring, make this an exciting area of research with the potential to transform healthcare.

4 APPLICATIONS OF MACHINE LEARNING AND IOT-BASED SOLUTIONS FOR CHRONIC DISEASE PREDICTION

Machine learning and IoT-based solutions have a wide range of applications in chronic disease prediction. Some of the major applications are shown in **Fig. 3** and explained below.

- **Early Diagnosis:** Machine learning and IoT-based solutions can be used to identify early signs and symptoms of chronic diseases. By analyzing large amounts of data generated by various IoT devices, machine learning models can identify patterns and predict the likelihood of a patient developing a chronic disease (Al-Jarrah et al., 2015).
- **Personalized Treatment:** Machine learning and IoT-based solutions can also be used to personalize treatment plans for patients. By analyzing a patient's medical history, lifestyle habits, and genetic makeup, machine learning models can recommend personalized treatment plans that are tailored to the patient's individual needs (Jiang et al., 2017).
- **Disease Management:** Machine learning and IoT-based solutions can also be used to monitor chronic diseases and manage their symptoms. For example, wearable devices such as smartwatches and fitness trackers can monitor a patient's heart rate, blood pressure, and other vital signs, and alert them or their healthcare provider if there are any significant changes (Majumder et al., 2017).
- **Prevention:** Machine learning and IoT-based solutions can also be used to prevent chronic diseases from developing in the first place. By analyzing data from various sources such as social media, mobile apps, and electronic health records, machine learning models can identify high-risk populations and recommend preventive measures (Dagliati et al., 2018).

Some of the benefits of using machine learning and IoT-based solutions for chronic disease prediction include:

- **Improved Accuracy:** Machine learning models can analyze large amounts of data from various sources and identify patterns that may not be visible to humans. This can lead to more accurate predictions and better treatment outcomes (Kourou et al., 2015).
- **Cost Savings:** By predicting and preventing chronic diseases before they become severe, healthcare costs can be significantly reduced. This can lead to cost savings for both patients and healthcare providers (Bates et al., 2014).
- **Patient Empowerment:** By providing patients with real-time data about their health, machine learning and IoT-based solutions can empower them to take control of their own health and make informed decisions about their treatment (Topol, 2019).

Overall, machine learning and IoT-based solutions have the potential to revolutionize the way chronic diseases are diagnosed, managed, and prevented. As more data is generated from IoT devices and machine learning algorithms become more sophisticated, the applications of these solutions in healthcare will continue to grow.



Fig. 3 Applications of Machine Learning and IoT-Based Solutions for Chronic Disease Prediction.

5 CONCLUSIONS

In conclusion, the development of machine learning and IoT-based solutions for chronic disease prediction presents both challenges and opportunities for the healthcare industry. While there are significant technical and ethical challenges to be addressed, the potential benefits of these solutions, including improved accuracy, cost savings, and patient empowerment, make them a promising area of research.

Through our review of the current state of research in chronic disease prediction using machine learning and IoT, we have identified several key findings. These include the types of chronic diseases studied, the types of data used, and the accuracy of existing models. Additionally, we have discussed the challenges and opportunities associated with the development of machine learning and IoT-based solutions for chronic disease prediction, including issues related to data privacy and bias.

Moving forward, it is important for researchers and healthcare providers to collaborate on the development and implementation of these solutions in a responsible and ethical manner. This includes addressing concerns related to data privacy, ensuring that algorithms are unbiased, and incorporating patient feedback into the design of these solutions.

Key concluding remarks of the study are as follows:

- The development of machine learning and IoT-based solutions for chronic disease prediction presents significant opportunities for improving patient outcomes and reducing healthcare costs.
- The accuracy of existing models varies widely, and more research is needed to develop robust and reliable algorithms.
- The use of these technologies presents significant ethical challenges, including concerns related to data privacy and algorithmic bias.

In conclusion, the use of machine learning and IoT-based solutions has the potential to transform the way chronic diseases are diagnosed, managed, and prevented. By leveraging these technologies, we can improve patient outcomes, reduce healthcare costs, and empower patients to take control of their own health. However, it is critical that we approach this area of research with caution and prioritize ethical considerations to ensure that these solutions are accurate, reliable, and accessible to all patients.

5.1 FUTURE SCOPE OF THE STUDY:

- Further research is needed to improve the accuracy and reliability of machine learning and IoT-based solutions for chronic disease prediction.
- Studies should explore the potential impact of these technologies on healthcare costs and patient outcomes.
- Ethical considerations related to data privacy and algorithmic bias must be addressed in the development and implementation of these solutions.
- The integration of patient feedback into the design of these solutions should be prioritized to ensure that they meet the needs and preferences of the end-users.
- Additional studies should examine the feasibility of scaling these solutions to different healthcare settings and patient populations.

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