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ARTIFICIAL INTELLIGENCE IN DIABETES MANAGEMENT: CURRENT APPLICATIONS, CHALLENGES, AND FUTURE PERSPECTIVES

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ABSTRACT: The global health burden of diabetes mellitus remains high, and fresh approaches are required beyond traditional medical management. Artificial intelligence (AI) has recently become a groundbreaking catalyst with great potential for revolutionizing all aspects of diabetes care, from forecasting and diagnosis to personalized therapy and risk prevention. This review discusses the use of machine learning, deep learning and algorithms derived from data analysis for the development of diabetes prediction, screening and continuous glucose monitoring. AI-enhanced methods for early identification of high-risk patients, management of insulin dosage and nutritional planning based on an individual's dietary and physical activity patterns using adaptive digital platforms are also developed. Further, smart systems integrated with wearable biosensors and telemedicine applications have enabled patient-centric as well as remote and continuous management. The article also points out AI's increasingly prominent application in automatic dietary monitoring, health education as well as early detection of diabetic complications including retinopathy and nephropathy. Although progress has been made in all of these areas, concerns including privacy, suboptimal-digital-literacy, algorithmic bias and regulatory barriers are some of the obstacles to widespread clinical implementation. Looking forward AI will be integrated with the Internet of Medical Things, generative and language models and precision-medicine frameworks to deliver safer, more equitable and effective diabetes care. Overall, AI represents a pivotal innovation that promises to shift diabetes management toward a predictive, preventive, and personalized healthcare paradigm.

INTRODUCTION:

Artificial Intelligence: AI is defined as a distinct field within computer science that develops systems that will allow for the ability to analyze complex data and solve various types of complex problems in many areas of application¹.

The benefit of Artificial Intelligence for diabetes care is its ability to quickly analyze large amounts of information and allow for the development of improved ways to treat and manage diabetes².

AI has significantly contributed to the development of several new technologies and methodologies in diabetes care including Wearables, Smartphones, Digital Health Tool, and real-time continuous monitoring of patient health and disease progression. Health care professionals should encourage patients to utilize AI to help maximize outcomes in managing diabetes.

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AI is making significant improvements in the following three areas of diabetes care: Patients, Health care providers, and Health care systems.

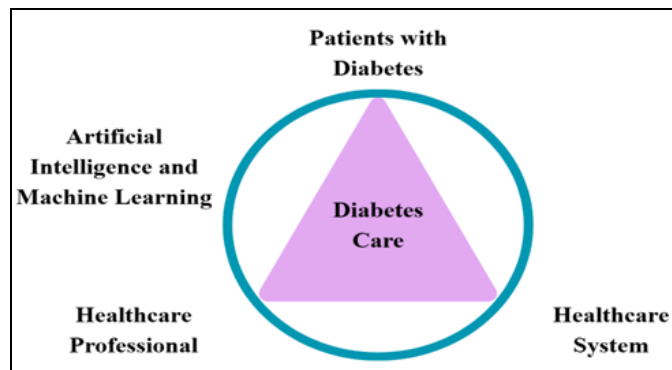


FIG. 1: SCOPE OF AI AND MACHINE LEARNING

For patients, AI allows for improved opportunities for patient self-management. For healthcare professionals, AI supports timely accurate clinical decision-making and adaptive follow-up strategies. From a Health systems perspective, AI allows for increased efficiency through optimized allocation and utilization of healthcare resources³.

Machine Learning (ML): Machine learning is a branch of AI that enables computers to learn from data and make decision and prediction. That is, machine learning is the development of algorithms that enable computers to learn from and make predictions based on data. The key word is automatic: machine learning is defined as the general approach to data sets that generates important results. Machine learning is based on the three concepts Data, Model, and Learning. The machine learning model can also be used in classification problems, often learning from past transactions to identify suspicious and fraudulent transactions, which are perceived as 'normal' and 'suspicious' transactions. Such suspicious transactions can then be filtered out for further processing and analysis through the use of machine-learning algorithms⁴.

Diabetes Mellitus: Diabetes mellitus constitutes a wide spectrum of metabolic disorders, all sharing the common feature of longstanding hyperglycemia that results from impairment in insulin secretion, action or both. Long-term exposure to elevated blood glucose leads to sustained structural/functional damage in several organs, including the retina, kidneys, peripheral nerves, heart and the vasculature.

Diabetes mellitus develops as a continuum of pathogenetic mechanisms. These mechanisms vary widely, from autoimmune destruction of the β -cells in pancreas and absolute lack of insulin to abnormalities which leads to resistance of cells to insulin. Disorders of carbohydrate and lipid metabolism are associated with the failure of insulin to act on its target tissues. This dysfunction can result from less insulin being made by the cells, or a reduced response to the signal pathways laid out by insulin, or both. Deficient insulin secretion is commonly intermingled with reduced sensitivity to insulin in individuals, complicating discernment of the most influential cause for hyperglycaemia⁵.

Polyuria, polydipsia, unexplained weight loss (with occasional polyphagia), and blurred vision are well described symptoms of marked hyperglycemia⁶. Prolonged excessive blood sugar can lead to altered growth and development, delayed wound healing, susceptibility to certain infections and cataracts. Without proper treatment, acute and life-threatening metabolic crises such as diabetic ketoacidosis or hyperosmolar hyperglycemia states can occur⁷.

Diabetes chronicles complications involve many organs of the body. These complications, such as diabetic retinopathy with the risk of visual loss, nephropathy leading to end-stage renal disease and peripheral neuropathy that predisposes patients to foot ulcers, amputations and Charcotarthropathy. Autonomic neuropathy can present with changes in gastrointestinal, genitourinary and cardiovascular function and sexual dysfunction⁸.

Dyslipidaemia and hypertension often coexist, which influences the global cardiovascular risk. Diabetes can be divided into two main groups from the etiopathogenetic point of view. Type 1 diabetes results from an absolute deficiency of insulin secretion, typically secondary to autoimmune-mediated β -cell destruction. Individuals at risk can often be identified by serological markers of autoimmunity and specific genetic profiles. Type 2 diabetes, which accounts for the majority of cases, is characterized by a combination of peripheral insulin resistance and an inadequate compensatory insulin secretory response. In many cases, hyperglycemia develops insidiously and may remain asymptomatic for an extended period.

During this latent phase, abnormalities in glucose regulation such as impaired fasting glucose or impaired glucose tolerance can be detected through biochemical testing before overt disease develops^{9, 10}.

Classification of Diabetes Mellitus:

Type 1 Diabetes: Type 1 diabetes (T1D) can often be identified well before clinical symptoms appear, as insulin secretion starts to progressively decline at least two years prior to diagnosis during this early stage, pancreatic β -cells become less responsive to glucose. The second phase of insulin secretion is greater when the first phase diminishes. Following diagnosis, the decrease in insulin sensitivity progresses more rapidly. A biphasic pattern of insulin loss has been confirmed by studies in the first years after diagnosis, with a higher initial rate of decline and the subsequent period of lower volume reduction.

Insulin secretion declines further with the passage of time until it virtually ceases to be produced. Blood glucose may trend towards the high-end of normal, and variability in glucose is evident during T1D onset. Metabolic biomarkers, including dysglycemia, can predict the development of disease in predisposed populations. Changes of the glucose and C-peptide levels allow for better risk estimates and prediction models as well¹¹.

Idiopathic Type 1 Diabetes: A rare variant of T1D, idiopathic diabetes does not have an autoimmune basis and overall presents milder disease than the classical autoimmune disorder. Individuals with this variety might have occasional ketoacidosis and diminished insulin secretion. It is seen more commonly in those with African or Asian heritage¹².

Fulminant Type 1 Diabetes: Fulminant T1D is a distinct and aggressive form of the disease first recognized in 2000. Like idiopathic T1D, it is not immune-mediated¹³. Ketoacidosis develops shortly after the onset of hyperglycemia, and C-peptide levels become undetectable despite extremely high blood glucose concentrations (around 288 mg/dL). Approximately 20% of Japanese patients with acute-onset T1D (roughly 5,000–7,000 cases) are affected by this variant, which is primarily documented in East Asian populations.

It is characterized by rapid and near-total destruction of β -cells, resulting in almost no endogenous insulin secretion. The condition is thought to arise from a combination of genetic and environmental triggers. An intense antiviral immune response, without the typical production of pancreatic autoantibodies, may be responsible for the β -cell loss. Fulminant T1D has also been reported in association with pregnancy¹⁴.

Type 2 Diabetes: In type 2 diabetes (T2D), impaired insulin secretion plays a central role in disease progression. Normally, insulin secretion adjusts according to insulin sensitivity to keep glucose levels stable. The relationship between these two factors is represented by the “disposition index,” which follows a curvilinear pattern. People with T2D have a reduced disposition index, indicating their inability to increase insulin production sufficiently to overcome insulin resistance.

Even though insulin levels in insulin-resistant, obese individuals with T2D are often higher than those in insulin-sensitive lean individuals, these levels are still inadequate relative to the degree of resistance. The first-phase insulin response to glucose is greatly reduced or absent, and the proinsulin-to-insulin (or C-peptide) ratio is elevated. Additionally, the maximal capacity to produce insulin and the ability of hyperglycemia to enhance insulin responses to non-glucose stimuli are markedly reduced. With time, hyperglycemia progresses and is more difficult to control because of the gradual decline in β -cell function an essential feature of T2D pathogenesis¹⁵.

Gestational Diabetes: Gestational hyperglycemia is associated with poor outcomes in both the mother and child. These risks exist irrespective of whether the increased blood glucose level is or acts like type 2 diabetes diagnosed before pregnancy or develops during it. There's also the higher risk of developing diabetes later in life for babies born to mothers with gestational diabetes¹⁶.

High maternal glucose is a significant contributor to pregnancy-related complications, such as preterm and large-for-gestational age births, macrosomia (birth weight >4.5 kg), higher rates of cesarean section deliveries, and preeclampsia.

Most of these problems arise from an overgrowth of the baby due to the high levels of maternal glucose.

There are a number of factors that may increase the risk of developing gestational diabetes, including family history of diabetes, maternal obesity, advanced maternal age and certain conditions such as polycystic ovary syndrome (PCOS), not being physically active and exposure to environmental toxins¹⁷. Diagnosis is established by the consensus definition of specific clinical criteria, including evaluation of fasting plasma glucose levels, 75 g oral glucose tolerance test, and other pertinent diagnostic parameters¹⁸.

Diabetes Technology: Technology for the management of diabetes, or "diabetes technology", includes a variety of both hardware (devices) and software (computer programs) that use Artificial Intelligence (AI). The goal of Diabetes Technology is to allow for continuous monitoring of glucose concentrations in the body; delivery of insulin based on those glucose levels; and individualized treatment plans, known as diabetes management programs. Recent developments in this area have greatly improved the ability to provide timely clinical decisions by moving away from "stand-alone" devices (e.g. blood glucose meters) and instead using intelligent systems that incorporate many different types of data from multiple sources and analyze them together.

One example of how AI is helping with diabetes care is the integration of AI into Continuous Glucose Monitor (CGM) systems. Through the use of machine learning algorithms, CGM systems are now able to make predictions about when a patient may experience low (<70mg/dl) or high (>180mg/dl) blood sugar levels based on their historical data as well as other factors such as diet and activity level, and determine when to send alerts to both the patient and their physician. Smart insulin pumps, and closed-loop systems allow the patient to have their insulin delivered automatically based on changes in blood glucose levels as well as historical data and physical exertion using predictive algorithms. As wearable technologies such as smart sock technology and ECG monitors become more widely available, they can help detect early signs of complications associated with

diabetes such as neuropathy, cardiovascular disease, etc. These new AI-enabled diabetes technology solutions allow for the development of individualized and forward-thinking diabetes management strategies, revolutionizing traditional digital health tools¹⁹.

Application of AI in the Prediction and Prevention of Diabetes:

Diabetes Onset Prediction: Prediction of the diabetes onset is an important part of a preventive care in that it aims at recognizing individual high-risk probability for developing the disease prior to expressing clinical symptoms. Early diagnosis allows for prevention of the development of diabetes, ultimately reducing the prevalence.

Predictive models were available before machine learning became popular, including classical statistical methods such as logistic regression, Cox proportional hazards models and Weibull distribution analysis. For example, Abbasi *et al.* showed that they could predict the risk of incident diabetes in individuals without diabetes over 5-10 years, with a concordance index ranging 0.74-0.94.

With the development of AI, ML has become an excellent tool to improve predictive accuracy beyond traditional methods. Choi *et al.* found that ML logistic regression models had an AUC of 0.78 in predicting the occurrence of new diabetes cases in hospitalized patients within 5 years. Similarly, Ravaut *et al.* employed an administrative health database to build a model with AUC 0.80 for 5 years diabetes prediction. Nomura *et al.* used a Gradient-Boosting Decision Tree algorithm for early prediction of diabetes. More recently, Zhang *et al.* developed a DL model of that integrated retinal imaging and clinical risk factors in order to predict and classify the risk of new-onset T2DM²⁰.

Management of Modifiable Risk Factors for Diabetes: Artificial intelligence can assist in determining the risk factors that are responsible for the development of diabetes since human evaluation may be hindered or biased when dealing with large and complex datasets. In identifying these modifiable risks, AI facilitates the creation of appropriate and personalized preventative strategies. Previous studies had revealed many genetic, clinical, anthropometric, demographic and

behavioral factors associated with the transition from NGH to diabetes (including from NGH to T1D, from NGH to T2D and from NGH to GD) or from GD to T2D.

AI-enabled predictors have identified multiple targetable risk factors that contribute to the risk for diabetes, including high blood pressure, high cholesterol, smoking, physical inactivity, poor dietary quality and overweight or obesity²¹.

Application of AI in the Screening and Classification of Diabetes:

Screening of Diabetes: The most classical diagnostic methods of diabetes lean on the invasive clinical measurements, influenced by ethnicity and habits. Due to the fact that early-onset of T2D is usually asymptomatic, a significant number of cases remain unidentified for years. Such a late diagnosis leads often to comorbidities and shortened life span.

To solve this issue, researchers are focussing on generating more accurate, cheap, and non-invasive diagnosis method that use for receiving all data. These requirements have driven the adoption of AI solutions able to analyze large and complex data sets (including those arising from wearable sensors and continuous monitoring devices) capable of very accurate classification and making screening more accessible. AI-based approaches with personalized screening strategies on high-risk populations could be a promising way to promote the public participation in early diabetes detection²².

AI applications in diabetes diagnosis predominantly focus on two major aspects. The first one is finding the hidden or unknown predictors of the disease. For example, Tapak *et al.* applied several AI algorithms, such as artificial neural network (ANN), support vector machine (SVM), fuzzy c-means, random forest model, logistic regression and linear discriminant analysis to the information of 6,500 participants in Iran and did not depend on blood glucose measure. Their results indicated that the AUC value for SVM model was higher than those calculated from logistic regression and linear discriminant analysis²³. Similarly, Maniruzzaman *et al.* compared different GP approaches with different kernels

(linear, polynomial and radial basis) against classical classifiers including linear, quadratic discriminant analysis and naïve Bayes. The radial kernel Gaussian process performed optimally²⁴.

The second line of research involves advanced sensing technologies and innovative new forms of data. Shu *et al.* studied the facial texture features for diabetes detection with 8 separate texture extraction methods. Their SVM model led to an impressive accuracy (99.02%), whereas sensitivity and specificity were estimated to be 99.64% and 98.26% respectively. Li *et al.* constructed a non-invasive risk prediction model *via* integration of tongue feature fusion and ML algorithms to achieve an accuracy (criterion) of 0.821, AUROC (area under the receiver operating characteristic curve) of 0.924 in pre-diabetes/diabetes prediction. Additionally, Zhang *et al.* demonstrated that deep learning models could accurately identify T2D based on retinal fundus images alone, or in conjunction with clinical data, yielding AUROCs between 0.85 to 0.93²⁵.

Technology in Diabetes Prediction: Artificial intelligence techniques such as data mining, machine learning (ML), and deep learning (DL) are increasingly being applied to predict the onset of diabetes by analyzing statistical and historical data. These methods rely on identifying common early signs of diabetes, including metabolic irregularities and hyperglycemia, which pose significant risks to vital organs such as the eyes, kidneys, and nervous system. Data related to these indicators are collected and then modeled by incorporating variables like age and gender to improve prediction accuracy²⁶.

Application of AI in the Comprehensive Management of Diabetes: The comprehensive management of diabetes includes various applications of artificial intelligence (AI) for risk prediction, continuous monitoring, treatment optimization and complication management. AI-assisted tools can analyze heterogeneous clinical data sets, including electronic health records, laboratory parameter values, lifestyle factors, and continuous glucose monitor (CGM) outputs, and facilitate risk stratification of patients based on their diabetes risk and progression potential.

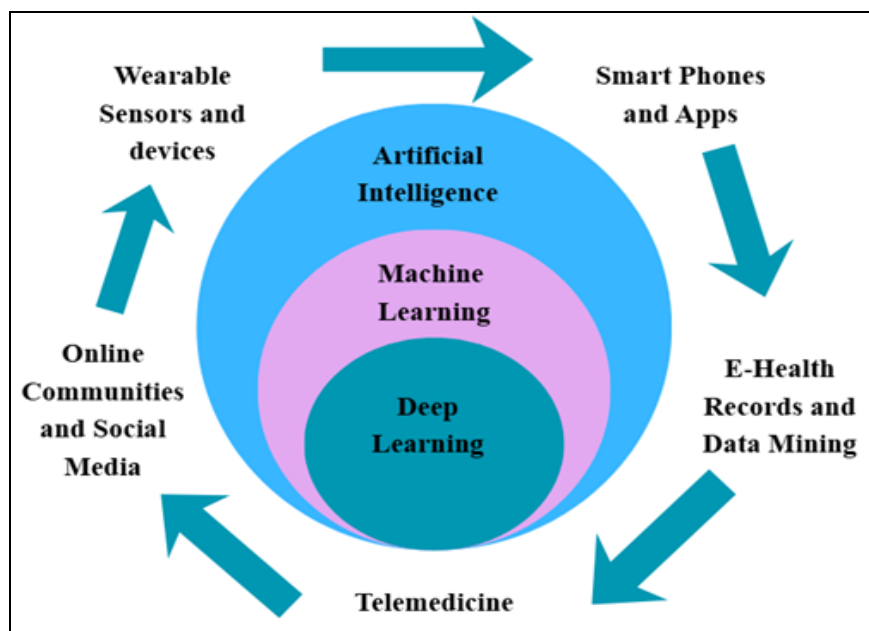


FIG. 2: APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN DIABETES CARE

Machine learning algorithms play an important role in analyzing longitudinal glucose data to allow early recognition of glycemic variability and metabolic control deterioration and are featured as part of the routine management of diabetes. AI-powered decision support applications take the interpretation of glucose data one step further by enabling the personalization of therapeutic and insulin dose adjustments based on how the patient responds to treatment. The use of predictive AI diagnostic models also leads to better anticipation

of diabetes-related complications and allows for the implementation of proactive preventive interventions. While AI provides valuable support across multiple aspects of diabetes care, the utility of AI to provide complete and comprehensive support for individuals with diabetes depends on the quality of the data sets being used, the diversity of the populations represented in the databases and the extent to which AI models have been validated in a clinical setting.

TABLE 1: SUMMARY OF AI APPLICATIONS IN DIABETES MANAGEMENT

S. no.	Application Area	Specific Task	AI/ML Techniques Used	Key Finding
1.	Prediction and prevention	Predict future onset of diabetes	Logistic Regression, Decision Trees, Deep Learning (DL)	Models can predict diabetes 5 years in advance.
2.	Screening and Diagnosis	Non-invasive screening for T2D	Support Vector Machines (SVM), Deep Learning, Gaussian Process.	DL models using retinal fundus images achieved high accuracy for detecting T2D.
3.	Glycemic Control	Predict blood glucose (BG) fluctuations	Recurrent Neural Networks, Artificial Neural Networks.	ML algorithms for predicting hypoglycemia showed high pooled sensitivity and specificity.
4.	Complication Management	Automated screening for diabetic retinopathy	Automated retinal imaging analysis	AI systems can anticipate complications like retinopathy, nephropathy, and cardiovascular disorders.

As a result, AI will continue to provide significant support for all aspects of diabetes care, but requires thoughtful evaluation, standardization and clinical oversight before AI can be integrated into clinical practice. Moreover, AI systems can anticipate the development of diabetes-related complications such as diabetic nephropathy, retinopathy, and

cardiovascular disorders through the analysis of comprehensive patient datasets. These predictive insights enable early diagnosis and preventive interventions for secondary complications. AI-driven platforms also enhance remote monitoring and telemedicine services by enabling continuous patient assessment and real-time diagnostic

adjustments. By integrating data from multiple sources and presenting a comprehensive view of the patient's health status, AI supports more informed and accurate diagnostic decisions. Collectively, these technological advances have strengthened the efficiency, precision, and timeliness of diabetes diagnosis, thereby improved patient care outcomes and alleviating the burden on healthcare systems.

Health Education: Health education involves more than giving information to patients; it sets the foundation for the self-management of diabetes. Alotaibi *et al.* designed the intelligent mobile diabetes management system, whose pilot study showed it could reduce HbA1c levels and improve participants' basic diabetes knowledge²⁷. Hamon and Gagnayre used natural language processing techniques on web forms to uncover patients' knowledge gaps and propose personalized educational plans. Most recently, Chen *et al.* used intelligent mobile health technology for diabetes education to assess its impact on glucose control with patients with T2D, who were starting pre-mixed insulin. The combination of the 12-week education and the insulin initiation helped in the management of T2D by causing a significant reduction in the patients HbA1c levels²⁸.

Automatic Diet Monitoring: Inaccurate self-reporting of food intake is a huge obstacle in dietary management of patients with diabetes²⁹. This highlights the need for automated solutions in dietary monitoring. Based on level of automation, a monitor system can be classified as semi-automatic or fully-automatic. For semi-automatic systems, users have to indicate the position of food on a plate, 'marking' the food. For fully-automatic dietary systems, users upload food pictures to a central system which estimates dietary composition. This means that photo analysis systems need to address image segmentation, food recognition and classification, volume estimation, and conversion of estimated volume to calorie. Recent advances in technology indicate an improvement in estimating energy intake from images of food. For instance, in the work of Vasiloglou *et al.*, the smartphone system GoCARB, specially designed for T1D patients, can estimate the carbohydrate content of a patient's meal³⁰. The estimations by GoCARB system did not differ from

those of dietitians for any meal size. Zhang *et al.* designed a system that automatically identifies food, records the calories and nutrients, and requires no user input³¹. When tested for 15 different food items, the system's accuracy exceeded 85%. Fang *et al.* expanded on the concept of "food energy distribution" to capture the four characteristics of food energy spatial arrangement in an eating scene. A four-layer generative adversarial network was implemented where the user inputs a food image and the network predicts an energy distribution image. The user can then estimate the energy from the food image based on the predicted energy distribution image. The average of the estimated energies was 209 kcal per eating occasion, suggesting more work is needed for accurate estimations³².

AI-Driven Dietary Recommendations: Maintaining healthy blood glucose levels through an appropriate diet is crucial for managing diabetes and alleviating stress on pancreatic islet β cells³³. A well-planned, individualized diet can help regulate both blood sugar and lipid levels while ensuring adequate intake of proteins and essential nutrients³⁴. Effective dietary recommendation systems for diabetic patients should be grounded in medical nutrition principles, take into account individual eating habits, and support the development of sustainable healthy behaviors.

Artificial intelligence assisted dietary recommendation systems are increasingly being explored as supportive tools for personalized nutrition management in individuals with diabetes. These systems utilize computational models to process dietary intake, metabolic responses, and lifestyle-related variables in order to generate individualized nutritional guidance. Previous studies have reported encouraging levels of concordance between AI-generated recommendations and expert dietary assessments when evaluated under controlled research settings. However, such outcomes are highly dependent on study design, dataset characteristics, and validation protocols, and therefore should not be generalized without caution. In addition, research has demonstrated substantial person-to-person variation in postprandial glucose responses following consumption of identical meals. Machine learning approaches that integrate factors such as habitual

food intake, physical activity, and gut microbiome composition have shown potential in addressing this variability by enabling individualized dietary strategies aimed at improving glycemic control. Despite these promising findings, AI-driven nutrition platforms currently function best as decision-support systems. Their broader clinical adoption requires further validation across diverse populations and should occur alongside professional dietary supervision rather than as a replacement for trained dietitians.

Physical Therapy: Diabetes management, which is a condition where blood sugar levels are outside the normal range, has to do with insulin resistance. When patients are not able to participate in regular exercise, they may experience difficulty managing their diabetes due to increased insulin resistance and lack of good glycemic control. Some of the challenges associated with implementing regular exercise include different patient capabilities, which may affect motivation levels and therefore adherence to exercise recommendations. Artificial Intelligence (AI) advances in technology have allowed health care providers to develop more individualised, data-driven approach to exercise by considering an additional variable to determine exercise recommendations for individuals - their current health status or condition and real-time context. AI-enabled digital coaching allows healthcare professionals to use digital coaching tools such as wearables, activity trackers, and data reported by patients, in order to provide the patient with the type, intensity, and duration of exercise recommendation according to what is appropriate for them at any given time. For instance, there are adaptive systems that adjust activity recommendations based upon both the environment in which the individual is exercising and the physical activity patterns of the individual.

Similarly, cloud-based intelligent exercise prescription platforms have also been shown to improve not only metabolic and cardiovascular outcomes in adult individuals, but also to be effective as part of diabetes care. Although these tools may have additional value as potential adjuncts to diabetes management, further studies need to be completed to determine the long-term effectiveness of these systems and how they can be incorporated into normal clinical practices^{35, 36}.

Blood Glucose (BG) Monitoring and Prediction:

In diabetes management, daily fluctuations in blood glucose (BG) are common due to varying carbohydrate intake, insulin activity, and other physiological factors. Accurately predicting these BG changes can provide early warnings of potential glycemic excursions, allowing patients and healthcare providers to act proactively.

With advancements in continuous glucose monitoring (CGM) technology, it is now possible to collect real-time glucose data to forecast future BG levels over timeframes ranging from a few minutes to several hours. Although CGM devices typically exhibit a mean absolute relative difference of about 9%, they remain integral to predictive research. Most studies focus on short-term predictions within 60 minutes, which have proven critical for timely diabetes management.

Among the machine learning (ML) techniques applied, artificial neural networks (ANNs) are the most widely used, followed by random forest and support vector machine (SVM) models. In a meta-analysis, Kodama *et al.* evaluated ML algorithms for predicting hypoglycemia and reported pooled estimates of 0.80 for sensitivity and 0.92 for specificity, showing strong diagnostic potential³⁷.

AI-based prediction systems have proven especially beneficial during challenging contexts, such as fasting periods. For instance, Elhadd *et al.* developed a machine learning algorithm that integrates clinical and demographic variables, physical activity patterns, and glucose variability to predict hyperglycemic events in patients with type 2 diabetes (T2D) undergoing fasting during Ramadan.

The model achieved impressive accuracy correctly identifying normal glucose levels in 95.2% of instances, hyperglycemic events in 82.6%, though it was less effective in detecting hypoglycemia events at 27.9%. Such studies highlight the growing potential of AI-driven tools and intelligent, context-aware systems in improving diabetes care through more precise exercise prescriptions and predictive monitoring. The continuous blood glucose monitoring helps to monitor the patient blood glucose level for easily

managing any problem occur when blood glucose level is immediately increased, in that condition AI driven device controlling blood glucose, the device show their response by sensors which is available in device that helps to managing glucose level.

Challenges: Despite the growing potential of artificial intelligence (AI)-based interventions in health education for type 2 diabetes mellitus, several challenges continue to limit their widespread adoption and long-term effectiveness. One of the primary barriers is user acceptance, as reported dropout rates in digital health interventions range between 15% and 20% in several studies. Complex system interfaces and limited usability have been associated with reduced engagement, particularly among older adults and individuals with limited digital literacy. In addition, inadequate access to advanced digital infrastructure and high costs of certain AI-enabled platforms further restrict their adoption in resource-limited settings. Another important challenge is the perceived lack of relevance and personalization in

AI-generated feedback. When users consider the recommendations to be repetitive or insufficiently tailored to their individual needs, long-term engagement tends to decline. This highlights the necessity of developing adaptive AI systems that incorporate patient-specific preferences, behavioral patterns, and contextual factors to sustain motivation and adherence.

Concerns related to data privacy and security also pose a significant obstacle to the implementation of AI-driven health education systems. These technologies rely heavily on the collection and processing of sensitive personal health data, necessitating robust data protection and cyber security measures. Growing public awareness of data breaches and misuse of digital health information has contributed to reduced trust in AI-enabled applications. Previous investigations have indicated that a substantial proportion of users remain apprehensive about the safety, reliability, and ethical use of AI-based health platforms.

TABLE 2: KEY CHALLENGES OBSTRUCTING CLINICAL TRANSLATION OF AI

S. no.	Challenge Category	Specific Issue	Impact on Adoption & Implementation
1.	User Acceptance & Adoption	Complicated user interfaces, Lack of perceived relevance	High dropout rates (15-20%). Discourages participation, especially from older adults.
2.	Data Security & Privacy	Patient concerns over sensitive health data, Insufficient regulatory policies	Patient hesitancy; nearly 60% of participants expressed apprehension about the safety of AI health apps.
3.	Digital Proficiency & Equity	Disparities in technology competence among patients	Patients with limited digital proficiency struggle to use apps effectively, which risks deepening existing healthcare disparities.
4.	Technical & Regulatory	Algorithmic bias, Lack of interoperability between systems, Regulatory complexities for medical AI	These barriers collectively impede large-scale clinical translation and foster a lack of trust.

Furthermore, the lack of comprehensive and harmonized regulatory frameworks governing AI applications and healthcare data privacy in many regions creates uncertainty for developers and end-users alike. Variations in national policies and ethical guidelines complicate the development and deployment of standardized AI solutions.

Finally, evidence from regional studies underscores the importance of contextualizing AI solutions to local technological infrastructure, healthcare systems, and policy environments. AI-based interventions that fail to consider regional socioeconomic and regulatory conditions may exhibit limited effectiveness and scalability.

Addressing these challenges through user-centered design, policy development, digital literacy initiatives, and ethical governance is essential for the sustainable integration of AI in diabetes health education³⁸.

Future Perspectives: The future of artificial intelligence (AI) in clinical diabetes management is evolving rapidly with the advent of generative models, which foster the development of inclusive and comprehensive medical AI systems. These generalist models could improve diabetes care through continuous monitoring of risk factors, early detection, optimization of medication dosages, and prediction of complications.

The integration of wearable devices and the Internet of Medical Things enables smooth data sharing with enhanced interoperability, cyber security, and reliable transmission capabilities further strengthened by advanced 5G network infrastructure. Large language models (LLMs) represent a major technological milestone, capable of engaging in natural, interactive communication and offering meaningful support to healthcare professionals. Building upon this, LLM-based autonomous agents with attributes such as responsiveness, initiative, and social intelligence have been introduced, allowing them to interpret complex medical data and perform multifaceted tasks beneficial for diabetes management.

These developments signal progress toward more universal AI systems, including artificial general intelligence, that can augment traditional clinical workflows by improving efficiency in data handling and decision-making. To ensure the effective and sustainable integration of AI in diabetes care, close collaboration among healthcare providers, data scientists, and AI developers will remain essential for ongoing innovation and refinement.

CONCLUSION: The use of Artificial Intelligence (AI) increases in healthcare, there is growing interest in how AI can provide support for diabetes prevention, diagnosis, and management. In this review, we describe how data-driven AI techniques will improve clinical and lifestyle data analysis and thus enhance clinical efficiency and patient engagement through Early Risk Identification, Continuous Glucose Monitoring and Personalized Therapeutic Planning. Despite these exciting opportunities, there are still many barriers that need to be overcome before AI tools can be adopted into routine clinical practice, including concerns regarding data security, equitable access to digital technologies, and absence of standardised regulatory frameworks for AI tools. Therefore, to successfully integrate AI into diabetes management, healthcare professionals must use AI's capabilities as complementary tools to assist healthcare professionals in their clinical judgement. Further research into the validation of such technologies, the ethical oversight of their use, and the development of inclusive systems for technology implementation are required to

responsibly and effectively use AI in the management of diabetes.

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