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Review Paper

A Review Article of Assessment of Medication Adherence in Type 2 Diabetes Mellitus Using Artificial Intelligence Applications

Dr. Vinothini M*, Dr. Mohamed Halith S, Priyadharsini R, Pugazhenthi A, Ragavi N, Ragupathi R, Rakshith N

Dhanalakshmi Srinivasan College of Pharmacy, Perambalur, Tamil Nadu, India..

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ABSTRACT

Background:Type 2 Diabetes Mellitus (T2DM) is a chronic metabolic disorder that requires continuous medication and lifestyle management to maintain proper glycaemic control. Poor medication adherence among patients is a major challenge that can lead to treatment failure, complications, and increased healthcare costs.Objectives:To assess medication adherence in patients with Type 2 Diabetes Mellitus using Artificial Intelligence (AI)-based identified mobile applications and evaluate their effectiveness in improving treatment adherence and clinical outcomes.Result:AI-based reminder apps improve medication adherence in Type 2 Diabetes Mellitus through timely alerts and personalized support. This leads to better glycaemia control, reduced HbA1c levels, and improved quality of life.Conclusion:The study was conducted over a period of 4 months in the Department of General Medicine. A total of 110 patients diagnosed with Type 2 Diabetes Mellitus were included based on inclusion and exclusion criteria. Baseline demographic and clinical data such as BMI, blood pressure, fasting blood sugar (FBS), postprandial blood sugar (PPBS), and HbA1c levels were collected. Patients were monitored regularly every 12 weeks. AI based mobile applications were used to assess medication adherence through reminder systems and patient monitoring, and the clinical outcomes were evaluated using biochemical parameters

INTRODUCTION

As per WHO and American Diabetes Association, Diabetes mellitus is a syndrome of multiple etiologists characterized by chronic hyperglycaemia with disturbances of carbohydrate, fat and protein metabolism resulting from defects in insulin secretion, insulin action or both. This disorder is often associated with long

***Corresponding Author:** Dr. Vinothini M
Address: *Assistant Professor, Department of Pharmacy Practice, Dhanalakshmi Srinivasan College of Pharmacy, Perambalur, Tamil Nādu, India.*
Email : vishali2026@gmail.com

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term complications, involving organs like eyes, kidneys, nerves, heart and blood vessels.

Diabetes has become a global problem, and the epidemic is most pronounced in Southeast Asia particularly India where an estimated 72 million people are believed to have diabetes and another 80 million have pre-diabetes. More than 90 – 95% of all patients with diabetes have type 2 diabetes. The treatment of type 2 diabetes has undergone rapid changes in the last decade, and several new drugs have been introduced in the market.

Artificial intelligence transforms type 2 diabetes mellitus care by enabling real time continuous glucose tracking, predictive subtype analysis, and individualized metabolic management plans via wearable sensors and digital twins. These AI interventions significantly improve glycemic outcomes, reduce weight, and lower medication reliance compared to standard clinical care Type 2 Diabetes Mellitus requires continuous medication to maintain proper glycaemic control.

However, many patients show poor medication adherence due to forgetfulness, lack of awareness, and complex treatment schedules. Artificial Intelligence based reminder and notification applications can support patients by providing timely alerts and monitoring medication use. Therefore, this study is conducted to assess medication adherence in patients with Type 2 Diabetes Mellitus using AI-based apps and to evaluate their role in improving treatment adherence and diabetes management.[1]

2.MEDICATION ADHERENCE

DEFINTION:

Medication adherence refers to the degree to which an individual's medication-related behavior aligns with established guidelines provided by a healthcare professional [2]. Medication adherence is the word used to describe people who take their prescribed drugs at the specified time, dosage, and frequency. It depends on patients understanding of their health condition and cooperation with healthcare practitioners. The process by which people take their prescription drugs as directed is known as medication adherence [3] .

The Significance of Adherence is crucial for improved therapeutic results in several clinical practice scenarios. Among them are:

1) Chronic conditions like diabetes and high blood pressure.
2) Thyroxin and insulin are examples of replacement therapy.
3) Pharmacological effect maintenance:
4) Oral hypoglycaemic and antihypertensive medications.
5) Maintaining serum medication concentrations to manage certain disorders, such as anticonvulsants.
6) Tuberculosis, HIV, and similar opportunistic infections are some diseases of public health relevance where non-adherence is a key challenge to achieving control.

Medication Adherence Classification:

1. Adherent
2. Partially compliant
3. Non-compliant.

Adhering to more than 70% of the prescribed medicine regimen is considered partially adherent and adhering to more than 80% of the prescribed regimen is considered adherent. Depending on the patient's views regarding the necessity and effectiveness of a specific medication, medication adherence may fluctuate daily and for different medications[4].

3.DEFINITION:

DIABETES MELLITUS

The most prevalent endocrine disease, diabetes mellitus (DM), affects more than 100 million people globally (6% of the total population). It is caused by the pancreas producing insufficient or ineffective insulin, which raises or lowers blood glucose levels. It has been demonstrated to damage several body systems, including blood vessels, eyes, kidneys, hearts, and nerves [5].

Hyperglycaemia, or increased blood glucose, is the primary symptom of diabetes mellitus, a complicated chronic metabolite disease caused by abnormalities in insulin secretion, action, or both. Due to its related problems, it is a global health concern with rising prevalence, substantial morbidity, and mortality. For diabetes to be effectively diagnosed, treated, and managed, it is essential to comprehend the pathophysiological mechanisms underlying the condition. Furthermore, because of the complexity of disease, variance in clinical presentation, and the limits of the available diagnostic instruments, the diagnostic procedure poses significant hurdles [6].

For the rest of their lives, people with diabetes must continue their treatment with medications, lifestyle modifications, and routine blood testing. Patients must take their prescription medications as directed to effectively manage their diabetes. Poor blood sugar monitoring brought on by inadequate medication use increases the risk of serious diabetes health concerns, such as heart issues and nerve damage [7].

AI powered mobile app helps patients with Type 2 Diabetes Mellitus (T2DM) manage their glycemic levels and stay consistent with their medication. It features secure login capabilities, customized dosing schedules, automated alerts, blood sugar tracking, appointment scheduling, and educational materials.

Additionally, an accessible dashboard allows users to easily track their daily regimen compliance, glucose patterns, and overall progress[8].

4.ETIOLOGY

Diabetes mellitus can be broadly categorized into

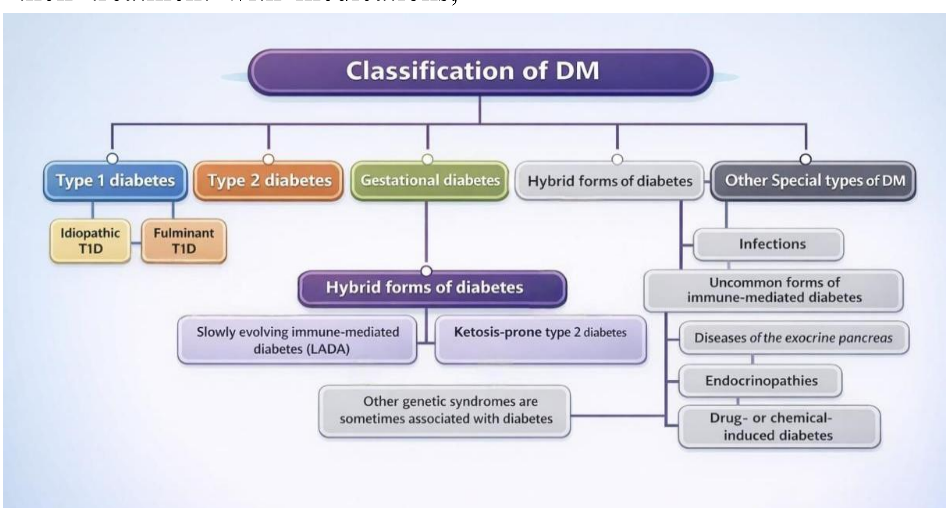

Figure 1: Classification Of DM [9]

1. TYPE- 1 DIABETES MELLITUS

Type 1 diabetes mellitus, a chronic condition, is also known as autoimmune diabetes mellitus. It is caused by a reduction in insulin secretion because of pancreatic β cell loss. Although signs of T1DM usually begin in infancy or adolescence, they can also develop later in adulthood. T1DM may develop because of T lymphocytes killing β cells, while the precise ethology is uncertain[10].

2. TYPE -2 DIABETES MELLITUS

Dysregulation of protein, lipid, and carbohydrate metabolism is a hallmark of type 2 diabetes mellitus (T2DM), which is caused by either insulin resistance, decreased insulin secretion, or a combination of the two. Compared to type 1 diabetes mellitus (T1DM) and gestational diabetes, type 2 diabetes (T2DM) is the most prevalent of the three main forms of the disease, making up over 90% of all cases [11].

To maintain appropriate glucose levels, insulin production fluctuates greatly in relation to insulin sensitivity. Given the severity of their insulin resistance, insulin-resistant obese T2D patients' absolute insulin levels are still unacceptably low, even if they are greater than those of insulin-sensitive lean control individuals [12].

3. GESTATIONAL DIABETES MELLITUS

Pregnancy related diabetes Hyperglycemia increases the risk of adverse outcomes for the mother, fetus, and unborn child. Whether hyperglycaemia is diagnosed as type 2 diabetes before or during pregnancy, there is always a danger. Growing up with diabetes is more common in babies born to mothers with gestational diabetes[13].

Hyperglycaemia during pregnancy, which results in larger neonates, is the main cause of the increased prevalence of pregnancy related problems, including premature birth, large for gestational age births, macrosomia (birth weight > 4.5 kg), caesarean delivery, and preeclampsia. Several risk factors, including a family history of the condition, obesity, advanced maternal age, polycystic ovarian syndrome, sedentary lifestyle, and exposure to environmental contaminants, might affect gestational diabetes[14].

Evaluation of fasting blood sugar levels, blood sugar levels following a 75 g oral glucose load, and other pertinent measures are among the criteria used to identify gestational diabetes.

5.SIGN AND SYMPTOMS

GENERAL SYMPTOMS

Many people with type 2 diabetes have no symptoms.

The following are examples of clinical manifestations:

1. Polyuria, polydipsia, polyphagia, and weight loss are classic symptoms.
2. Vision blurriness
3. Paresthesias of the lower extremities
4. Yeast infections (such as male Di extremities').

TYPE 1 DIABETES MELLLITUS

- Extreme hunger
- Excessive thirst
- Inadvertent weight loss are some signs of type 1 diabetes.
- Additionally, frequent urination, fatigue and fuzzy vision.

TYPE 2 DIABETES MELLITUS

- Increased appetite
- Increased thirst
- Increased urine
- Blurred vision

Additionally, it might result in recurrent infections. This is because the body finds it more difficult to heal when glucose levels are high[15].

GESTATIONAL DIABETES

Diabetes during pregnancy: Because many of the changes may be like those that occur during pregnancy.

There may be no obvious symptoms or indicators of gestational diabetes. However,

- Weaknesses
- Blurred vision
- Intense thirst
- Nausea and
- Recurrent skin

Vaginal or bladder infections are possible signs and symptoms[16].

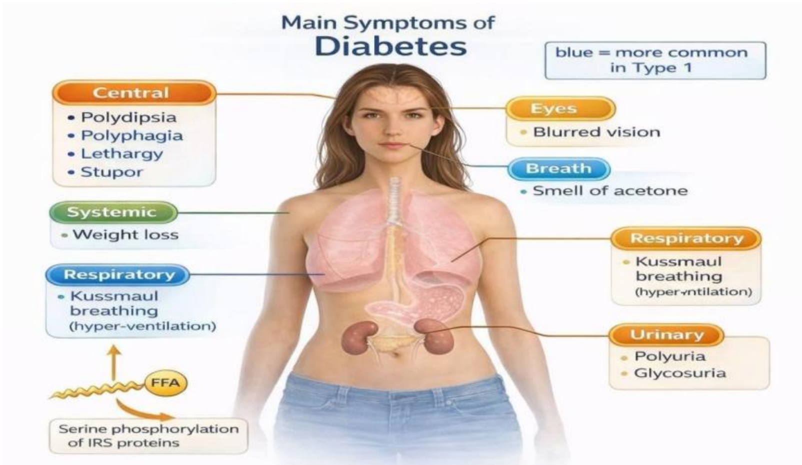

Figure 2: Signs And Symptoms [17]

6.DIAGNOSIS

Currently, the American Diabetes Association (ADA) correctly classifies diabetes into four types: type 1diabetes, type 2 diabetes, and other specific types of the disease from various causes, including gestational diabetes.

The American Diabetes Association's (ADA) diagnostic criteria include the following;

A minimum of 126 mg/dL (7.0 mmol/L) of fasting plasma glucose (FPG), ora 75g oral glucose tolerance test (OGTT) with a plasma glucose level of 200 mg/dL (11.1 mmol/L) or higher after two hours, or when a patient shows the usual symptoms of hyperglycaemia, a random plasma glucose level of 200 mg/dL (11.1 mmol/L) or higher hyperglycaemia crisis. Blood pressure that is continuously greater than 135/80 mm Hg Being overweight and having one or more additional risk factors for diabetes (such as having a first-degree relative with the condition, having blood pressure higher than 140/90 mm Hg, and HDL <35 mg/dL and/or triglyceride levels >250 mg/d.

The purpose of therapy for the goal of type 2 diabetes is to keep blood sugar (glucose) under control. Levels, which can lower the chance of complications developing Diabetes related conditions like retinopathy, nephropathy, cardiovascular conditions and neuropathy[18].

7.EPIDEMIOLOGY

Diabetes is becoming more common in many parts of the world due to fast urbanization and economic growth, by 2035, it is anticipated that over 590 million individuals would have been diagnosed with type 2 diabetes. T2DM is recognized as a global disease despite geographical differences in its incidence and prevalence. In Obesity and overweight, sedentary lifestyles, and increased consumption of diets high in processed and red meat, refined carbs, and sugar sweetened beverages are the primary drivers of the global T2DM epidemic[19].

People with diabetes are more likely to experience a number of serious health problems. Regularly high blood glucose levels can lead to serious health issues that affect the heart, blood vessels, kidneys, eyes, nerves, and teeth. In almost all high-income nations, diabetes is a leading cause of heart disease, blindness, kidney failure, and lower limb amputation[20].

MECHANISM

A collection of related disorders known as diabetes mellitus (DM) occur when the body is unable to regulate blood sugar levels, especially glucose.

- The blood carries glucose, which provides the body with the energy it needs to perform daily functions.
- The liver converts a person's nutrition into glucose.
- The glucose then enters the bloodstream.
- Many hormones, including insulin, regulate blood glucose levels in healthy individuals.
- Insulin is produced by the pancreas, a small organ located between the stomach and liver.
- The pancreas also produces other essential digestive enzymes that are delivered directly to the gut.
- Insulin makes it easier for glucose to enter body cells from the circulation[21].

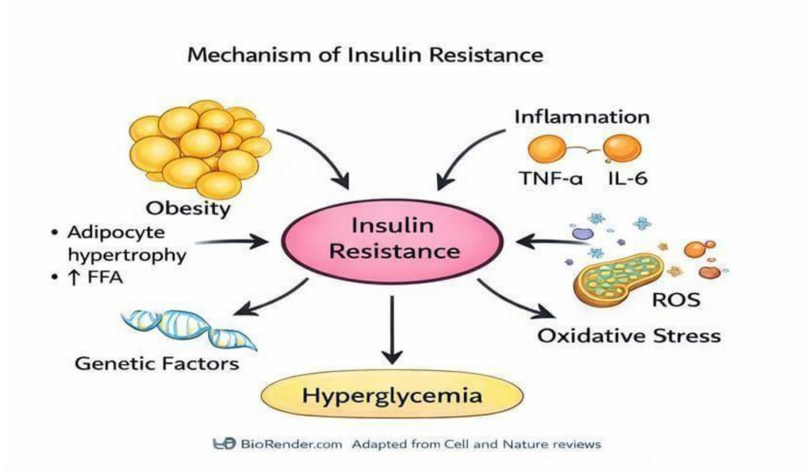

Figure 3: Mechanism of DM [22]

8.PATHOPHYSIOLOGY

Genetics + Environmental Factors

↓

Insulin Resistance (IR)

↓

↓ Glucose uptake (Muscle & Adipose) ↑ Hepatic glucose production

↓

Hyperglycaemia

↓

β–cell Dysfunction (↓ Insulin secretion)

↓

Persistent Hyperglycaemia

↓

Type 2 Diabetes Mellitus

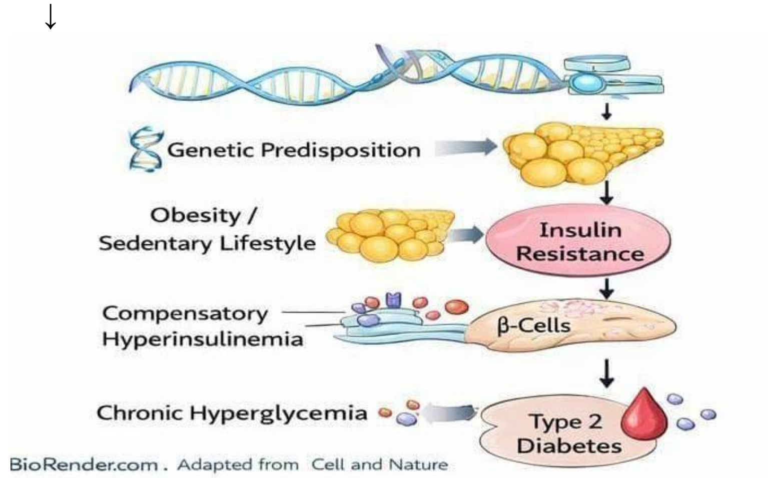

Figure 4: Pathophysiology of DM [23].

9. METHODOLOGY

1. STUDY DESIGN:

The study was designed and conducted as a prospective observational study.

2. STUDY DURATION:

4 Months

3. STUDY LOCATION:

The study was carried out at Department of General Medicine in DS Hospitals.

4. SAMPLE SIZE:

The sample size was calculated using Rao software as 110 patients based on diabetic population, by using margin error 5% and confidence interval 95%, the sample size was calculated.

5. INCLUSION CRITERIA:

Patients who are diagnosed with type 2 diabetes mellitus and Age > 18 years.

6. EXCLUSION CRITERIA:

- Pregnant women's and lactating mothers
- Patients who are diagnosed with type 1 diabetes mellitus.

7. STUDY PROCEDURE:

The study is carried out by selecting patients randomly from Department of General Medicine having type 2 DM.

Designing the data collection form collection form

↓

Identification and recruitment of subjects based on inclusion and exclusion criteria

↓

Collection of baseline profiles of patients along with demographic details

- Physical profile (BMI, BP) Diabetic profile (FBS, PPBS, HbA1c,)
- Regular follow-up of patients was done and data was collected every 12 weeks
- Assessment and comparison of safety and efficacy of both groups (By using biochemical parameters such as FBS, PPBS, HbA1c and adverse effects) Conclusion.

10.EXPECTED OUTCOME

AI based mobile applications are expected to improve medication adherence in patients with Type 2 Diabetes Mellitus through reminders, monitoring, and personalized support (Babel et al., 2021; Inamdar et al., 2013; Ghozali, 2024; Zavaleta-Monestel et al., 2025; Reis et al., 2025). This improved adherence leads to better glycaemic control with reduced HbA1c, FBS, and PPBS levels (Felemban et al., 2025; Nguyen et al., 2008), resulting in enhanced clinical outcomes and reduced complications (Zheng et al., 2018; American Diabetes Association, 2019). Ultimately, effective diabetes management improves patient engagement, supports healthcare decision-making, and enhances overall quality of life (Tian et al., 2025; Prasad, 2025).

11.NON-PHARMACOTHERAPY TYPE 2 DM

A combination of medication and lifestyle modifications is used to treat type 2 diabetes

1. Lifestyle modifications:

The lifestyle choices of individuals, including their diet, weight management, physical activity, tobacco use and alcohol consumption, indicate that weight loss is the primary factor in preventing diabetes.

2. Weight loss:

Several successful methods for achieving weight loss include adhering to low-fat and low calorie diets, consuming diets high in Fiber and protein, and engaging in exercise[24].

3. Exercise:

Many studies have highlighted the importance of physical activity (PA) for health, and recent evidence now points to the positive improvements associated with exercise in type 2 diabetes mellitus (T2DM) [25].

5. ROLE OF ARTIFICAL INTELLIGENCE

Recent developments in artificial intelligence (AI) have opened new possibilities for resolving persistent problems in the medical field[26].

Artificial Intelligence (AI) can significantly improve treatment outcomes by helping patients follow their medication schedules correctly. Medication adherence means taking medicines at the right dose, at the right time, and for the prescribed duration. Poor adherence often leads to treatment failure, complications, and increased healthcare costs. AI-based systems help solve this problem.

- AI -Based Reminders System
- Personalized Treatment Support
- Monitoring Patient Behavior
- Early Detection of Non-Adherence
- Improved Clinical Outcomes

MOBILE APPLICATIONS:

Data analytics and machine learning are used by mobile health apps to forecast adherence patterns and customize treatments. While certain apps, like Medi SAFE, have improved hypertension patients' self-reported adherence somewhat without improving clinical results like blood pressure management, others have had a bigger impact. For instance, the Health Belief Model based mHealth app that related to WhatsApp produced statistically significant gains in blood pressure reduction and adherence[27].

SMART DEVICES:

Smart technologies have demonstrated promise, especially wearable technology and digital inhalers in long term allergic and respiratory disorders. AI powered smartwatch systems and devices like InHanzdPlus accurately identify instances of drug administration, enabling real time tracking of adherence. Additionally, Opportunities arise when AI is combined with blockchain and Pulsatile Drug Delivery Systems (PDDS), for safe data administration and customized, on demand drug delivery, particularly pertinent in Comorbid patients and polypharmacy[28].

12.LIMITATIONS

1. AI is better at treating than diagnosing, even though it has been shown to reduce healthcare expenses[29].
2. Yet many evaluations have not factored in the startup and ongoing expenses required for the deployment of AI[30].
3. Data accessibility and processing power are also required to accelerate its development[31].
4. While Internet based clouds make it possible to access more data, it might be difficult to filter pertinent, clear, and significant data [32].
5. These difficulties offer a great deal of opportunity for ongoing advancement and creativity in the artificial intelligence space[33].

FUTURE DIRECTIONS

The pathophysiological underpinnings of type 2 diabetes have become better understood in recent years. Precision medicine still faces difficulties because of its complexity and diversity. Precision medicine focuses on customizing treatment plans according to a patient's genetics, lifestyle, environment, and the unique molecular causes of their illness. Future studies on the pathophysiology of type 2 diabetes will progressively emphasize precision, personalization, and in depth investigation at the molecular mechanism level, according to precision medicine.

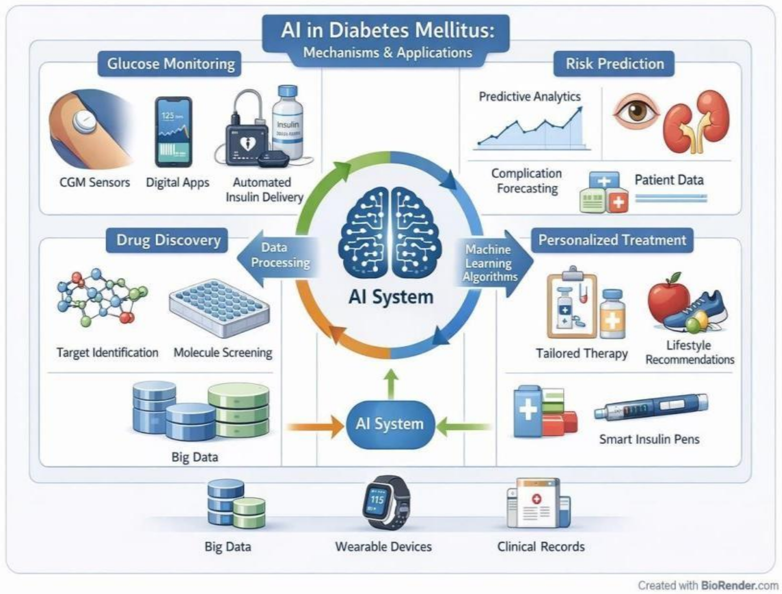

Figure 5: AI Based diabetes mellitus[34]

AI-DRIVEN PATIENT MONITORING AND REMINDERS

Intelligent patient monitoring and reminder systems are among the simplest ways to use AI to improve drug adherence. AI powered smart devices and mobile apps maintain medication schedules and notify patients when doses are due using information from patient inputs, sensors, and electronic health records.

AI driven solutions customize notifications depending on each patient's behaviors, preferences, and adherence patterns, in contrast to traditional reminders that are general and static. For instance, the system might modify reminder times or raise the frequency of warnings during that time if a patient routinely forgets to take their evening doses.

To optimize the distribution method whether by text messages, voice calls, app notifications, or wearable device alerts machine learning algorithms examine responses to reminders. By identifying physiological indicators linked to drug effects or side effects, wearable technologies improve monitoring even more. AI enabled smart pill dispensers can monitor pill consumption, identify missing doses, and automatically alert caretakers or medical professionals, allowing for prompt assistance. Additionally, AI systems can be integrated with more comprehensive health management platforms to provide comprehensive support that links lifestyle elements like nutrition, exercise, and symptom tracking with drug adherence. This integration reinforces positive behaviors by assisting patients in understanding how adherence directly affects their health.

Adaptive reminders and real-time monitoring boost patient involvement, lower forgetfulness a frequent reason for non-adherence and encourage accountability. These technologies also give clinicians useful information that allows for remote adherence monitoring and customized care plan modifications[35].

Computer vision a sophisticated branch of Artificial Intelligence enables automated drug identification and verification using photos captured on smart devices. By utilizing deep learning models, specifically Convolutional Neural Networks (CNNs), the system evaluates key physical attributes such as shape, color, dimensions, markings, and packaging to confirm the accurate drug and dosage prior to intake.

This mechanism significantly reduces medication mistakes, avoids dosing inaccuracies, and elevates patient safety, which is particularly vital in managing chronic conditions like Type 2 Diabetes Mellitus (T2DM)[36,37].

Additionally, computer vision systems can identify compromised tablets, expired pharmaceuticals, improper insulin pens, and discrepancies between prescribed and intended doses. Integrating these vision-based tools into mobile health (mHealth) platforms facilitates instant medication authentication and automated intake logging, ultimately enhancing regimen compliance and mitigating preventable adverse drug reactions[37,38].

Adaptive Medication Reminders

Driven by artificial intelligence and machine learning, adaptive medication systems tailor notification schedules to an individual's daily routine, historical compliance, and interaction patterns. In contrast to static, time based alerts, these dynamic systems continuously process user data to automatically refine reminder timing, frequency, and delivery methods, thereby optimizing patient engagement and regimen adherence.[39,40]

Contemporary research indicates that AI driven adaptive notification platforms substantially enhance compliance by flagging patients susceptible to dose omissions and deploying tailored interventions. By integrating reminders with educational insights, motivational cues, and behavioral support, these systems foster superior regimen adherence, optimized glycemic management, and long-term diabetes self regulation[40,41].

Synthesis of Existing studies and research gaps:

Recent research shows that AI powered mobile health apps effectively help people with Type 2 diabetes manage their condition, stay engaged in their care, and take their medications as prescribed. By using predictive analytics, machine learning, and smart reminders, these tools improve blood sugar control, reduce missed doses, and offer personalized support [42-44].

Multiple systematic and narrative reviews indicate that AI driven interventions outperform traditional reminder systems in boosting medication adherence by offering adaptive alerts, tracking patient behavior, and providing immediate feedback.

Furthermore, connecting AI with continuous glucose monitors (CGMs), wearable technology, and electronic health records (EHRs) strengthens patient tracking and facilitates prompt clinical actions [45-47].

Although these findings are encouraging, current research exhibits several key drawbacks. Most studies rely on small sample sizes, short evaluation periods, and inconsistent methodologies, which makes direct comparison challenging. Furthermore, existing literature primarily focuses on short term medication tracking rather than assessing long-term clinical impacts, such as sustained HbA1c reduction, prevention of diabetes complications, overall healthcare utilization, and cost effectiveness [46-48].

Another significant limitation is that current AI models lack broad applicability. The majority of predictive algorithms have been trained and tested on datasets from specific healthcare institutions or high-income nations, making them less suitable for diverse populations. Critical demographic and social factors such as ethnicity, socioeconomic status, health literacy, digital skills, and regional healthcare infrastructure are frequently overlooked during model development[47,48].

Data privacy, cybersecurity, algorithmic transparency, and ethical concerns also present major hurdles to the widespread adoption of AI driven adherence tools. Many studies offer limited transparency regarding data governance, how machine learning models reach their decisions, or compliance with healthcare regulations. Resolving these issues is vital for building clinician confidence and driving patient adoption of AI-assisted medical technologies [42,48,49,50].

CLINICAL SIGNIFICANCE

- AI has changed the way diabetes is prevented, detected, and managed, which can help in bringing down the global prevalence of 8.8%.
- Case-based reasoning, machine learning, deep learning, and neural networks enable predictive population risk stratification, automated retinal screening, enhanced decision making, and self management.Artificial Intelligence (AI) will cause a paradigm shift in diabetic management through data driven precision care.
- AI positively impacts medical professionals by supporting decision making and remote monitoring.

13.STUDY LIMITATIONS

This study was based only on previously published articles and did not include direct patient data. Limited number of studies were available on AI apps for medication adherence in Type 2 Diabetes.

- Different AI applications have different features, which made comparison difficult.
- Some studies were conducted for a short period, so long term effects are not clear.
- Some patients may not have smartphones or internet access, which can limit the use of AI based applications.
- Patient factors like age and digital knowledge may also affect the use of these apps.

CONCLUSION

The implementation of AI based notification and reminder applications in patients with Type 2 Diabetes Mellitus significantly enhances medication adherence through timely alerts, behavioral monitoring, and personalized support. Improved adherence leads to better glycaemic control, which is reflected by a reduction in HbA1c test values, indicating decreased disease severity and improved clinical outcomes. As a result, effective management of Diabetes.

Mellitus is achieved, ultimately contributing to an enhanced quality of life among patients.

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