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Review

Strategies for Early Detection and Management of Type 2 Diabetes in Adult Populations

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Abstract

Type 2 Diabetes Mellitus (T2DM) is marked by insulin resistance and beta-cell dysfunction, contributing to a global health crisis exacerbated by rising obesity, sedentary lifestyles, and aging populations. This review examines strategies for early detection and management of T2DM in adults, highlighting advancements in diagnostic methods such as Glycated Albumin (GA) and Glycated Serum Protein (GSP), which offer improved sensitivity and specificity over traditional HbA1c tests. Continuous Glucose Monitoring (CGM) provides real-time glucose data, enhancing management but facing challenges such as excessive costs and insurance limitations. Effective early detection of prediabetes, combined with lifestyle interventions and pharmacological treatments, plays a crucial role in managing T2DM. Emerging therapies, including advanced medications and bariatric surgery, show promise for improving glycemic control and reducing complications. A multidisciplinary approach, integrating patient education, behavioural changes and innovative technologies, is essential for optimizing management strategies. Addressing these aspects will help mitigate the impact of T2DM and improve patient outcomes globally.

Keywords: *Type 2 Diabetes Mellitus (T2DM), Early Detection, Continuous Glucose Monitoring, Prediabetes*

Introduction

Type 2 Diabetes Mellitus (T2DM) is defined by a relative deficiency of insulin due to dysfunction in pancreatic β-cells and insulin resistance in target tissues (1). Between 1980 and 2004, the global incidence and prevalence of type 2 diabetes increased four times due to rising obesity rates, sedentary lifestyles and an aging population (2). Advancements in understanding of T2DM highlight that it often develops due to impaired insulin secretion by pancreatic β-cells, coupled with insulin resistance in skeletal muscle, liver and adipose tissue. Individuals with prediabetes have HbA1c levels between 5.7% and 6.4% and can transition to T2DM at an annual rate of 3% to 11% (3).

In 2015, diabetes was the sixth leading cause of disability, placing a significant burden on individuals and health systems with costs estimated at US$825 billion (4). Cardiovascular disease remains the primary cause of morbidity and mortality related to T2DM. Effective management involves controlling glucose, lipid levels, and blood pressure to reduce complications and slow disease progression. Intensive glucose management is critical to prevent microvascular complications, including retinopathy, nephropathy and neuropathy (1).

Quality outcomes are improved through early screening and intensive, patient-centered management. This approach integrates structured education, self-management, and psychological support, guided by the latest guidelines, and facilitated by a multidisciplinary team (5). Advances in understanding the pathophysiology of diabetes enable more precise, tailored treatments through precision medicine. For patients under 25, managing T2DM involves dealing with complex phenotypes that may require intensive care over many years to prevent microvascular and macrovascular complications. For elderly patients 65 and older, treatment must balance diabetes management with other health issues, cognitive impairments, and the risk of hypoglycemia (1).

The presentation and progression of T2DM can vary widely, and atypical symptoms may complicate diagnosis. Even while weight loss and exercise are successful lifestyle modifications at first, weight gain is common (6-8). However, those with prediabetes who effectively reduce their body weight and continue to maintain an active lifestyle can have better lipid profiles, lower cardiovascular risk and a lowered chance of developing diabetes (9).

T2DM is a chronic condition requiring ongoing medical care, patient self-management, and multifaceted risk reduction strategies. These strategies aim to normalize blood glucose, lipid levels, and blood pressure to minimize both acute and long-term complications, including retinopathy, nephropathy, neuropathy, heart attacks, and strokes. T2DM should be approached as a heterogeneous disorder with multiple pathophysiological abnormalities, varying susceptibility to complications, and different responses to treatment. Addressing T2DM effectively requires uncovering its molecular causes and tackling the obesity epidemic (10). The global prevalence of diabetes among adults is around 8%, with T2DM accounting for over 90% of cases. This prevalence is expected to exceed 10% by 2040 (11). While the rise in diabetes among older adults is clear, the increasing prevalence of T2DM among young people is a more recent and pressing concern.

Delaying the progression of T2DM is mostly dependent on early diagnosis and treatment. Prediabetes or intermediate hyperglycemia is the diagnosis given to people whose blood glucose levels are above normal but below the diabetic threshold. Prediabetes indicates an elevated risk of progressing to diabetes, whereas moderate hyperglycemia describes elevated glucose levels not yet at the diabetes threshold, representing a continuum toward diabetes (12).

Review

The global rise in T2DM among older adults is driven by increasing life expectancy and exposure to risk factors like obesity and sedentary lifestyles. It is expected that over 253 million older adults worldwide would have diabetes by the year 2045 (13). T2DM in older adults' results from worsening

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β-cell function and rising insulin resistance. The pancreas initially compensates by producing more insulin, but chronic hyperinsulinemia eventually impairs insulin responses. Ageing increases these problems through increased fat, decreased muscle mass, and reduced physical activity. Inflammation declines in regulatory T cells and muscle function deterioration further exacerbates insulin resistance (14).

There are various key drivers that contribute to the rise of T2DM in adults including early life determinants, dietary habits, physical activity, socio-economic influences, genetic predispositions and specific conditions like non-alcoholic fatty liver disease (NAFLD) **(Table 1)** (11).

Table 1. Key factors for T2DM in youth (11)

Factor	Summary
Early life	Intrauterine environment affects obesity and T2DM risk. Rapid weight gain and post-partum malnutrition increase the risk.
Diet and obesity	High-calorie, sugar-rich diets contribute to obesity and T2DM. Sweetened beverages and substantial portion sizes are major factors.
Physical activity	Inactivity boosts obesity risk. Declining exercise levels among youth are linked to T2DM risk.
Socio-economic	Deprivation impacts obesity and T2DM risk, often due to lifestyle choices rather than lack of healthy options.
Family history	Strong family history is linked to earlier T2DM onset. Genetic risk varies by ethnicity.
Gender and Polycystic ovarian syndrome (PCOS)	T2DM is more common in females and those with PCOS. Gestational diabetes also increases risk.
NAFLD	Adults with T2DM frequently have NAFLD, which is a significant risk factor for the disorder.

Early detection of T2DM

Numerous alternate diagnostic techniques have been suggested to improve early identification. Compared to haemoglobin A1c (HbA1c), glycated albumin (GA) is a new biomarker that indicates average glucose levels over a period of two to three weeks and represents short-term glycaemic fluctuations. Studies reveal that the sensitivity and specificity of GA tests are higher, leading to better early diabetes diagnosis. For example, sensitivity is 78% when HbA1c and GA are combined, but only 50% when HbA1c is used alone. Most undiagnosed diabetics can be identified by GA levels ≥17.1%, and the use of GA in conjunction with fasting glucose reduces false-positive rates by 33.75% when compared to fasting glucose alone. Because of this, GA is a useful tool, especially for people who have normal fasting glucose but are at higher risk (12).

Glycated Serum Protein (GSP) testing is an emerging biomarker reflecting glycemic control in diabetic patients (15). Compared to HbA1c, it provides a simple, rapid, and accurate assessment that is less affected by other metabolic variables. Studies have indicated that GSP exhibits elevated sensitivity and specificity, making it a useful instrument for diabetes surveillance, especially in those with conditions like anaemia and renal impairment. A study that found a strong positive link between fructosamine levels and HbA1c suggests that GSP and HbA1c can be helpful for glycaemic monitoring in patients who are receiving chemotherapy, have anaemia, or have impaired renal function in addition to patients with concomitant illnesses like cancer (16). GSP testing has shown potential in early diabetes diagnosis and complication prediction (17). A 2016 study highlighted that GSP effectively predicted diabetes based on 2-hour glucose and HbA1c levels in overweight and obese youth aged 10 to 18 (18). Additional research supports the value of GSP for screening and predicting diabetic complications (19, 20).

Another advanced method is Continuous Glucose Monitoring (CGM), which records glucose variations including postprandial excursions

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constantly. Intermittent testing may overlook patterns and dynamic changes in glucose levels, while CGM offers a full picture of glucose levels throughout the day. With the ability to detect 15% more cases of prediabetes than previously found, it is helpful in controlling prediabetes. The American Association of Clinical Endocrinologists' 2022 Clinical Practice Guideline for Developing Diabetes Care Plans provides into great depth about the measurements and use of CGM. However, CGM has drawbacks that affect its usability and accessibility, including high prices, technological difficulties and inconsistent insurance coverage (12).

In individuals younger than 25 years, distinguishing between various forms of diabetes can be challenging due to overlapping phenotypic features. C-peptide levels, a surrogate marker for circulating plasma insulin, can aid in this differentiation. In type 1 diabetes, C-peptide levels are typically undetectable up to three years after diagnosis, which helps distinguish it from other forms of diabetes.

Diagnosis of maturity onset diabetes of the young (MODY) requires high clinical suspicion, especially in slim patients under 25 years with mild disease and a strong family history of diabetes. Accurate MODY diagnosis often involves genetic testing for mutations in key genes such as Hepatocyte Nuclear Factor 1 Alpha (HNF-1α), Hepatocyte Nuclear Factor 4 Alpha (HNF-4α), and Glucokinase (GCK) (21).

Latent autoimmune diabetes in adults (LADA) can be mistaken for T2DM due to its similar presentation. However, LADA is more closely aligned with type 1 diabetes in its rapid progression and short duration of onset, typically requiring insulin therapy within about six months. Given the complexity of diabetes classification, new β-cell-centric treatment frameworks are recommended to address these diagnostic challenges (22).

Management

Management of T2DM in adults

Effective management of T2DM in adults involves a multifaceted approach that includes lifestyle modifications and pharmacological treatment. Some cases are also indicated for bariatric surgery. This comprehensive management strategy aims to achieve glycemic control, reduce the risk of complications, and enhance overall quality of life. The American Association of Clinical Endocrinologists (AACE) guidelines support a general approach that balances age, life expectancy, and comorbidities, but do not provide specific guidance for different age groups (23).

Lifestyle modifications

Diet

Dietary management is a cornerstone of T2DM management. A balanced diet focusing on low glycemic index foods, high fiber intake, and controlled portion sizes can help manage blood glucose levels and maintain a healthy weight. The American Diabetes Association (ADA) recommends a diet rich in vegetables, fruits, whole grains, lean proteins, and healthy fats, while limiting saturated fats, sugars, and refined carbohydrates. The National Institute for Health and Care Excellence (NICE) also emphasizes the importance of dietary management, suggesting that individuals with T2DM should reduce their intake of saturated fats and simple sugars and adjust their calorie intake according to their weight management goals (24).

Physical activity

Regular physical activity is crucial for managing T2DM. Exercise helps improve insulin sensitivity, aid weight control, and reduce cardiovascular risk. The ADA suggests at least 150 minutes of moderate-intensity aerobic activity per week, spread over three or more days, with resistance training included on two or more days per week (25). For older adults, who may face mobility and health limitations, tailored exercises such as chair-based activities or low-impact aerobics can be beneficial (26).

Weight management

Weight management is crucial for individuals with T2DM due to the strong link between obesity and diabetes risk. Excess weight exacerbates insulin resistance and contributes to poor glycemic control,

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increasing the likelihood of complications. Effective weight management through lifestyle changes such as a balanced diet and regular physical activity can significantly improve diabetes outcomes. Interventions focusing on weight reduction not only enhance blood glucose control but also reduce the risk of developing related health issues, underscoring the importance of integrated strategies for managing obesity in diabetes care (27).

Pharmacological treatment

Oral medications

Oral antidiabetic agents are often the first line of treatment for T2DM. Metformin, a biguanide, is typically the initial medication due to its efficacy in lowering blood glucose levels and its favorable side effect profile (28).

Rapid decline in beta-cell function may contribute to the faster loss of glycemic control and earlier need for insulin therapy in T2DM younger adults compared to older individuals with T2DM. While some adults can maintain glycemic control for the first 2–3 years with lifestyle and metformin, insulin is often preferred as initial therapy. Approximately one-third of those receiving basal insulin may subsequently discontinue it as glycemic control improves, although about half of these patients may need to resume insulin within a few months due to poor control (29, 30). The type of insulin used, and monitoring methods have insignificant effect on glycemic control or complication status (31).

Injectable medications

Several oral and injectable glucose-lowering therapies, such as Dipeptidyl Peptidase-4 (DPP-4) inhibitors, Glucagon-Like Peptide-1 (GLP-1) agonists, and Sodium-Glucose Co-Transporter 2 (SGLT2) inhibitors, offer therapeutic options with benefits on weight, insulin resistance, and beta-cell preservation.

Bariatric surgery

Bariatric surgery significantly improves T2DM management in obese adults' patients, often leading to remission or substantial control of the disease. Procedures like Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy have shown significant benefits, including considerable weight loss and improvements in glycemic control. These surgeries can lead to remission or substantial management of T2DM by altering gastrointestinal anatomy and metabolic pathways, which enhances insulin sensitivity and reduces blood glucose levels. Additionally, bariatric surgery has been associated with improvements in cardiovascular risk factors, further contributing to overall health benefits. However, there are noted potential risks, including surgical complications and nutritional deficiencies, which require careful management. Long-term follow-up is crucial to monitor and address these risks effectively (32).

Prevention of T2DM

Preventing T2DM is vital to avoid long-term medication and complications. Effective strategies include managing obesity and impaired glucose regulation through lifestyle changes and, if necessary, medications (33, 34). The US Diabetes Prevention Program (DPP) found that lifestyle modifications, like increased physical activity and a low-fat diet, reduced diabetes risk by 58% compared to a 31% reduction with metformin over 2.8 years (1). The DPP Outcomes Study (DPPOS) reported a 27% reduction in diabetes incidence with lifestyle changes and an 18% reduction with metformin, alongside improved cardiovascular risk scores (35). Challenges in real-world application include low participation, insurance coverage issues, and cost concerns. Programs like the UK's Diabetes Prevention Programme aim to address these challenges effectively (36).

Future directions

Future directions for managing T2DM in adults should prioritize enhancing early detection through advanced diagnostic tools and biomarkers, personalizing treatment via precision medicine to match individual genetic and lifestyle profiles, and leveraging digital health technologies for continuous monitoring and patient engagement. Additionally, there is a need for comprehensive research into the long-term safety and efficacy of

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new therapies, including pharmacological agents and bariatric surgery. Addressing behavioural and lifestyle intervention challenges, such as cost and accessibility, alongside promoting integrated care models that involve multidisciplinary teams, will be crucial for improving management strategies and patient outcomes, reducing the disease's burden.

Conclusion

Managing T2DM effectively requires integrating advanced diagnostic tools, such as GA and CGM, with personalized treatment and lifestyle changes. Multidisciplinary approaches and emerging therapies, including pharmacological agents and bariatric surgery, are crucial. Addressing cost and accessibility challenges will improve patient outcomes and reduce the global burden of T2DM.

Disclosures

Author Contributions

The author has reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Not applicable

Consent for publications

Not applicable

Data Availability

All data is provided within the manuscript.

Conflict of interest

The authors declare no competing interest.

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