

The Sugar Trap in Diabetes Mellitus: Understanding the Disease, Pathophysiology, Complications, Early Detection and Prevention -A Narrative Review

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ABSTRACT

Diabetes mellitus is a group of metabolic disorders characterised by elevated blood glucose levels (hyperglycaemia) and represents a major and growing global public health challenge. However, very few people are aware about how diabetes develops, its types, symptoms and what are the serious complications which are preventable if can diagnosed earlier. This narrative review aims to explain the development of diabetes, understanding of the symptoms and its complication while highlighting the importance of prevention, early detection, and long-term management. The article first describes how the body normally regulates blood glucose through the actions of insulin and glucagon before explaining the mechanisms of type-1 and type-2 diabetes. Secondly, it discusses the common symptoms of diabetes and the effects of prolonged high blood glucose on major organs, including the eyes, kidneys, nerves, heart, and feet. Finally, evidence-based approaches for preventing type-2 diabetes and reducing the risk of developing complications through healthy lifestyle habits, regular health screening, and appropriate medical care are presented. Educating the public about how diabetes develops may positively influence the adoption of healthy lifestyle choices, promote early diagnosis, and support better self-management among individuals living with diabetes. Public education remains an essential component to decrease the growing burden of diabetes and its complications.

Keywords

Diabetes mellitus; Type-1 diabetes; Type-2 diabetes; Blood glucose; Insulin; Diabetes prevention; Diabetes complications; Public health; Health education.

INTRODUCTION

Diabetes mellitus (DM) is one of the globally, rapidly increasing chronic, non-communicable diseases. It is a major public health problem due to its high mortality and morbidity. It includes a group of long-term metabolic disorder of carbohydrate metabolism characterized by high glucose levels in blood, a condition known as hyperglycaemia caused by either insufficient insulin production or cellular resistance to insulin, or both^{1,2,3}. Chronic hyperglycaemia disrupts other metabolic functions and damages various organs of the body leading to the development of disabling and life-threatening health complications^{1,2,4}. According to the World Health Organization (WHO), more than 830 million people are living with diabetes globally in 2022, and most living in low- and middle-income countries³. The International Diabetes Federation estimated in 2025 that roughly 589 million adults, aged 20-79 are living with diabetes globally⁵. This statistic shows that 1 in 8 adults are at high risk of developing type 2 diabetes. This number is expected to increase

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to 853 million by 2050⁵. High blood sugar does not usually cause immediate problems, leading diabetes can go unnoticed for many years. However, if blood sugar remains high over a long period, it gradually damages blood vessels and nerves in the body and cause serious complications on the heart, brain, kidneys, eyes and feet leading to disability and premature death globally².

It is important to understand how the body normally regulates blood sugar and what goes wrong in development of diabetes, and why healthy lifestyle choices and early detection are so important. In this narrative review, we highlight about the development of diabetes mellitus, its types, pathophysiology, complications and why early detection and prevention matters.

How Does the Body Normally Control Blood Sugar?

The body normally regulates blood sugar primarily using two key hormones, insulin and glucagon, which manage how cells absorb, use, and store sugar (Figure 1). This important job is carried out by the pancreas; an organ located behind the stomach that secretes these key hormones insulin and glucagon. Every time we eat,

the carbohydrates in food are broken down into glucose, a type of sugar that is the main source of energy for the body. When blood glucose rises after meals, specialised cells (β -cells) in the pancreas releases insulin in the blood stream that allows more glucose to move from the blood into the body's cells to produce energy and stores the excess as glycogen in the liver and muscles⁶. Several hours after eating or during fasting, blood sugar levels start to fall. If blood sugar drops, the pancreas secretes glucagon to stimulate the liver to release stored glucose to the blood stream, ensuring a steady energy supply to vital organs organs⁶. In healthy people, the role of insulin is to reduce blood glucose levels when they become too high whereas that of the glucagon is to raise blood glucose levels when they become too low. Thus, insulin and glucagon work together in regulating blood glucose levels to prevent them from becoming dangerously high or low. When this finely balanced system no longer works properly, blood sugar level will remain high causing the development of diabetes mellitus⁷. Thus, the opposing and balanced actions of insulin and glucagon help maintain normal glucose homeostasis⁷.

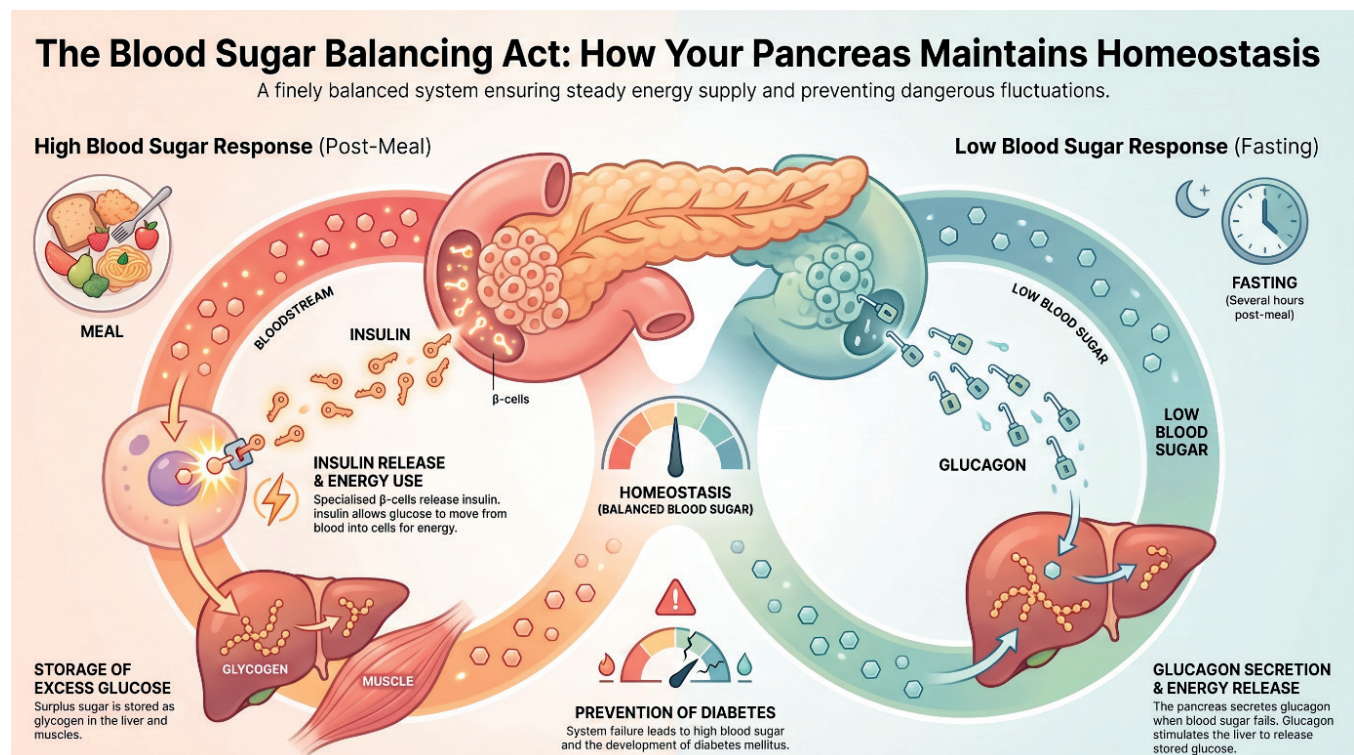


Figure 1: Normal Blood Sugar Regulation

Types of Diabetes Mellitus

Type-1 and type-2 diabetes are the two major forms of diabetes where in both the types raise blood sugar level but develop for different reasons, and require distinct treatments^{2,8}. Other recognized forms of diabetes include gestational diabetes and specific types caused by genetic conditions -monogenic diabetes, pancreatic disease-related diabetes, or certain drugs and chemicals induced diabetes².

Pathophysiology of Diabetes Mellitus

Type-1 Diabetes: How it Develops?

Type-1 diabetes represents for 5–10% of all diabetes cases⁹. It develops due to auto-immune destruction of the insulin-producing β -cells of the pancreatic islets, resulting in deficiency of insulin (Figure 2). Normally, the immune system protects the body from harmful bacteria and viruses. However, in people with type-1 diabetes, immune system mistakenly identifies these healthy β -cells of the pancreatic islets as harmful and gradually destroys them. As more insulin-producing cells are destroyed, the pancreas produces less and lesser insulin, eventually, there is not enough insulin to move glucose from the blood stream into the body's cells and this absolute insulin deficiency results in type-1 diabetes^{2,9}. There is an excess of glucose in the blood but the body's cells are unable to use it as a source of energy, resulting increased blood glucose level while the body's tissues are "starved" of the energy they need. Individuals suffering from type-1 diabetes need lifelong insulin replacement therapy as the body is unable to produce the insulin¹⁰. Scientists believe that type-1 diabetes develops due to a combination of genetic factors and environmental triggers such as certain viral infections, pesticide exposure, and changes in the gut microbiome. But the exact mechanism is still not fully understood¹¹.

Type-2 Diabetes: How it Develops?

Type-2 diabetes typically develops much more slowly than type-1 diabetes, often taking years or decades to progress. It affects significantly more people, comprising 90–95% of all diabetes cases². In type-2 diabetes, there is decreased biological responses to insulin, a problem known as insulin resistance² (Figure 2). During this condition, insulin becomes ineffective and initially

countered by the pancreatic over production of insulin to maintain blood glucose level for many years. For this reason, at the beginning of type-2 diabetes, most patients do not show any symptoms². However, with disease progression, the pancreatic β -cells dysfunction gradually makes the cells becoming less effective, resulting reduced insulin production. As insulin production continues to decline, it is unable to maintain glucose homeostasis, producing hyperglycaemia^{1,12}. Researches now recognize that type-2 diabetes is a multi-system disorder involving complex interactions. Besides the pancreas, other organs such as the liver, muscles, fat tissue, kidneys, intestines, and brain also contribute to poor blood glucose control. In skeletal muscle, impaired insulin signalling reduces glucose uptake. Liver suppresses glucose production as the blood sugar is already high. Adipose tissue dysfunction contributes to increased free fatty acid availability and inflammatory signalling. Abnormalities in incretin (gut hormone) biology, renal glucose handling, pancreatic α -cell function releasing too much glucagon and central regulation of energy metabolism may also contribute to abnormal blood sugar regulation⁷. Thus, these organs collectively influence glucose storage and production, helping to explain why type-2 diabetes develops gradually and why both lifestyle changes and targeted medical treatment are often needed to achieve glycaemic control or good blood glucose control¹³.

Several factors increase the risk of developing type-2 diabetes. The *modifiable risk* factors include obesity or being overweight, especially with an excess of abdominal fat, unhealthy eating habits, and physical inactivity. The *non-modifiable* risk factors include older age, genetics, ethnicity and family history of diabetes¹³. Asian people have a higher incidence rate compared to white American and UK people¹³. Although some risk factors such as age and genetics cannot be changed, a person can lower his or her chances of getting type-2 diabetes by adopting a healthier lifestyle^{12 14}.

In short, type-2 diabetes develops because the body's cells become less responsive or resistant to insulin and over time, the pancreas is no longer able to produce enough insulin to keep blood glucose level under control. Understanding how type-2 diabetes develops highlights the importance of healthy lifestyle habits and early intervention in preventing or delaying the disease.

Pathophysiology of Diabetes Mellitus: Type 1 vs. Type 2

The fundamental difference lies in **absolute insulin deficiency (Type 1)** versus **insulin resistance and progressive dysfunction (Type 2)**.

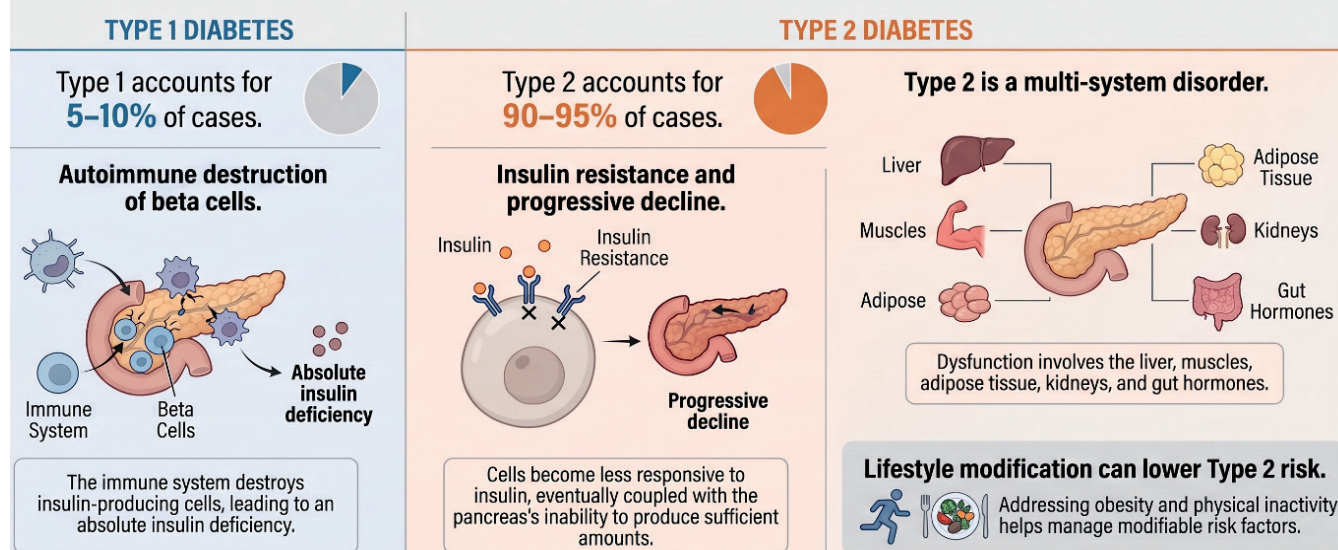


Figure 2: Pathophysiology of Diabetes Mellitus

What Are the Symptoms of Diabetes?

The classical or common symptoms of diabetes people may experience just before they are diagnosed are the '3P's: polydipsia, polyuria, and polyphagia, respectively refers to excessive thirst, urination, and hunger^{2,15}. Other symptoms include: feeling tired or lacking energy, blurred vision, delayed wound healing, frequent skin, gum, or urinary tract infections, unexplained weight loss (more common in type-1 diabetes)^{2,9}. Some people with newly diagnosed type-1 diabetes, particularly children, may first present with diabetic ketoacidosis (DKA), a serious acute complication².

Diabetes symptoms develop because body cells lack glucose for energy, causing sugar to build up in the blood. Symptoms in type-1 diabetes usually appear rapidly, while in type-2 diabetes they develop gradually and can remain unnoticed for years until a routine check-up or complication occurs^{2,8}.

Why Is High Blood Glucose Harmful?

High blood glucose without proper treatment, continues to damage the body silently. Though the symptoms may be mild or even absent in the early stages, persistently high blood glucose gradually damages blood vessels and nerves in the body. Over time, this can cause damage

to almost every organ, including the heart, brain, eyes, kidneys, and feet². Many of these complications can be prevented or delayed through early diagnosis, good blood glucose control, a healthy lifestyle, regular medical check-ups^{2,8} and physical activities.

Complications

The complications of diabetes tend to occur slowly over the years before becoming noticeable. However, once they occur, it significantly alters their health and quality of life. Acute complications include hypoglycaemia, diabetic ketoacidosis, hyperglycaemic hyperosmolar state, and hyperglycaemic diabetic coma.

Diabetes-related complications are often grouped into two main categories: (i) microvascular complications (damage to small blood vessels) and (ii) macrovascular complications (damage to large blood vessels). Microvascular complications include damage such as to eye (retinopathy), kidney (nephropathy) and nerves (neuropathy). While macrovascular complications involve heart (heart attacks and coronary artery disease), brain (stroke) and legs (leg ulcer)^{2,16}.

Figure 3 and the following sections explain some of the most common complications of diabetes and, more importantly, what can be done to reduce the risk of developing those complications.

THE SILENT DAMAGE OF HIGH BLOOD GLUCOSE

Persistently high blood glucose silently erodes blood vessels and nerves, leading to life-altering complications across the entire body.

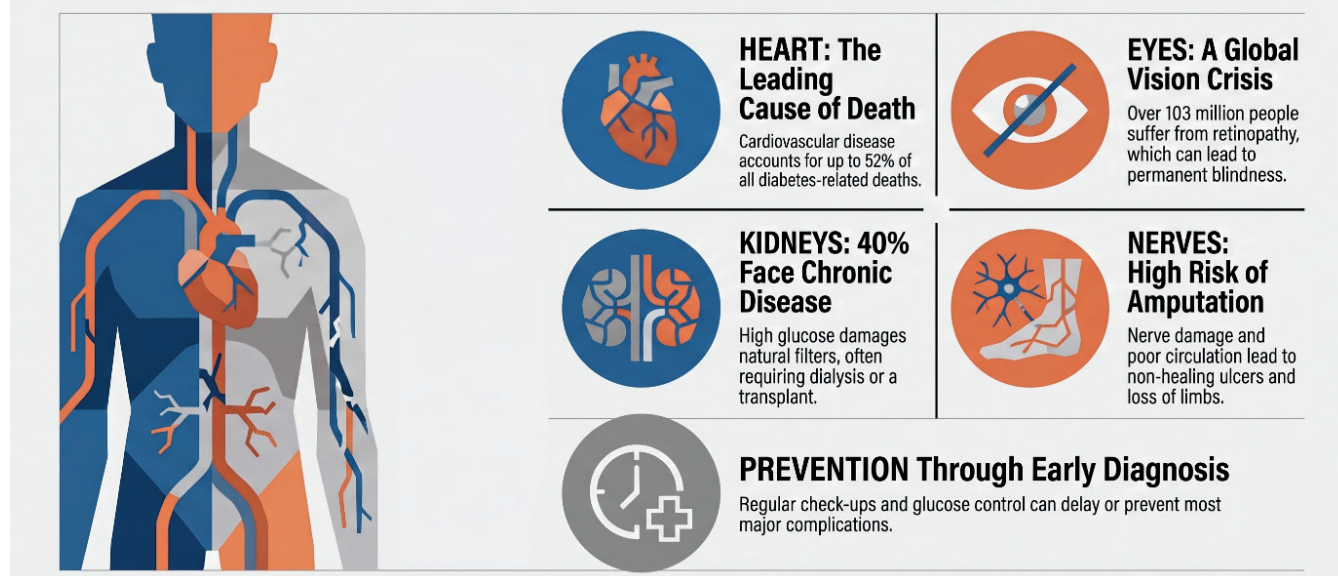


Figure 3: Common Complications of Diabetes Mellitus

Eye Complication: Diabetic Retinopathy

High blood glucose can damage the tiny blood vessels at the back of the eye (retina), the light-sensitive tissue that enables us to see. The condition is called diabetic retinopathy. In the early stages, it may not cause noticeable symptoms. However, as the condition progresses, it can result in blurred vision, difficulty to see things clearly, and in severe cases, permanent vision loss¹⁷. Diabetic retinopathy is becoming increasingly common worldwide. Globally approximately 103 million people are suffering from diabetic retinopathy and this number is expected to rise to 160.5 million by 2045¹⁷.

Kidney (Body's Natural Filtering System) Complication: Diabetic Nephropathy

The kidneys act as the body's natural filters (nephron), removing waste products and excess fluid from the blood through urine. Persistently high blood glucose can slowly damage these filters, causing diabetic nephropathy. Chronic kidney disease associated with diabetes occurs in approximately 20–40% of people with diabetes. In some individuals, it can progress to kidney failure requiring dialysis or kidney transplantation¹⁸. The impact is significant because kidney disease also

puts high strain on heart and blood vessels. Individuals suffering from both diabetes and kidney disease face a much higher risk of serious health complications compared to those without kidney involvement¹⁹.

Nerve Complication: Diabetic Neuropathy

Long-term high blood glucose can damage nerves, responsible for sensation throughout the body, a condition known as diabetic neuropathy. Diabetic neuropathy causes numbness and tingling sensations²⁰, burning/stabbing pain²¹, and reduced sensation that puts people at higher risk of foot and leg injury, ulcers, and infections, which in turn, increases the risk of amputation²². Diabetes may also affect other nerves that control body processes such as digestion, bladder control, heart rate, sexual function and blood pressure²³.

Foot Complication: Diabetic Foot Ulcers

Due to high blood glucose that persists for many years, nerve damage may occur in the feet causing peripheral neuropathy, leading to loss of sensation, tingling, or numbness. As a result of loss of protective sensation, a person may not notice small cuts, blisters, or wounds.

Moreover, diabetes reduces blood flow to the feet. Thus, leading to peripheral arterial disease, where blood vessels supplying the legs become narrowed, causing

leg pain while walking, reduced blood flow to the extremities resulting in coldness. The impaired tissue perfusion causes the presence of non-healing ulcers or infected wounds on the feet^{24,25}. In severe infection, diabetic foot ulcer may become a serious complication and difficult to treat and may require amputation of part of the foot or leg²⁵. Diabetic foot ulcers are a leading cause of disability in people living with diabetes affecting 6.3% people globally²⁶ and contribute greatly to poor quality of life^{27,28}.

Heart, and Brain Complications: Heart Attack, Stroke

People with diabetes have a higher risk of diseases affecting the heart and large blood vessels (coronary artery diseases) and these conditions are known as cardiovascular complications. Coronary heart disease results from accumulation of fat or atherosclerotic plaques within the coronary arteries impeding blood flow to the heart, resulting in angina or more severe myocardial infarction which is commonly known as a heart attack²⁴.

Stroke can occur when blood supply to the brain is interrupted or blocked due to atherosclerosis and endothelial dysfunction. This ischaemic stroke is more common in diabetic patients, when a blood vessel in the brain is damaged. Haemorrhagic strokes involving bleeding into the brain although less common, but have been observed in diabetic patients²⁴.

Hypertension is a common complication noted among the diabetic people²⁹. The coexistence of arterial hypertension and type-2 diabetes increases the risk of heart failure and stroke by 5 to 6 times compared to having hypertension alone³⁰. The major risk factors include hypertension, dyslipidaemia, obesity, smoking, chronic kidney disease, and physical inactivity. Consequently, diabetes care should extend beyond glycaemic control. Therefore, appropriate management of blood glucose level, blood pressure, cholesterol levels, smoking cessation and maintaining a healthy lifestyle are important to prevent cardiovascular and microvascular complications². The pharmacological therapies are selected according to individual cardiovascular and renal risk³¹. Cardiovascular disease is the leading cause of death for people with diabetes, accounting for 44% of death in type 1 diabetes and 52% in type 2 diabetes³².

Diagnosis

Routine health screenings are vital for people having risk factors such as overweight or obese, those with a family

history of diabetes, hypertension, hyper-triglyceridemia and adults aged >40 years². Early detection of diabetes allows treatment and lifestyle changes to begin before serious complication occurs.

Diabetes can be diagnosed using HbA1c or plasma glucose measurements. In non-pregnant individuals, diagnostic criteria include an HbA1c $\geq 6.5\%$ (48 mmol/mol), fasting plasma glucose ≥ 126 mg/dL (7.0 mmol/L), or a 2-hour plasma glucose ≥ 200 mg/dL (11.1 mmol/L) during a 75-g oral glucose tolerance test. A random plasma glucose ≥ 200 mg/dL (11.1 mmol/L) is diagnostic in a person with classic symptoms of hyperglycaemia or a hyperglycaemic crisis. In the absence of unequivocal hyperglycaemia, abnormal results should be confirmed².

Prevention of Diabetes

The type-2 diabetes can often be prevented or delayed among individuals at increased risk. Research has consistently shown that healthy lifestyle such as regular physical activity, healthy diet, and maintaining a healthy weight, can greatly reduce the risk of developing type-2 diabetes, especially among people with prediabetes^{33,34,35}.

Prediabetes is an early stage where blood glucose levels are higher than normal but less than the diabetic range. At this stage, they are at high risk of developing type-2 diabetes and other diseases such as heart disease, stroke and other serious complications³⁶, although most people have no symptoms, they may not realise that are at high risk. With healthy lifestyle changes such as regular physical activity, healthy eating, and weight management, many people can delay or even prevent the development of type-2 diabetes³³. A quality diet, discipline and drugs are the principles of diabetic management³⁷.

Diabetes can be prevented by following activities:

Staying Physically Active

Regular physical activity helps the body to use insulin more effectively, allowing blood sugar to be controlled within a healthy range. Regular exercise helps to maintain a healthy weight, improves heart health, and lowers the risk of many chronic diseases. Brisk walking, cycling, swimming, dancing, gardening, and household chores all contribute to a better health. Adults should do at least 150-300 minutes (two and half to five hours) of moderate-intensity aerobic physical activity each week, or at least 75-150 minutes (one hour 15 minutes to two and half hour) of vigorous-intensity

aerobic physical activity, or an equivalent combination of moderate-intensity and vigorous-intensity activity throughout the week for substantial health benefits; Adults also should do muscle-strengthening activities at moderate or greater intensity that involve all major muscle groups on two or more days each week³⁸.

Choosing a Healthy Diet

Healthy eating is one of the best ways to prevent and live well with type-2 diabetes. A balanced diet should include plenty of non-starchy vegetables, fruits, whole grains, legumes, lean protein, dairy products with minimal added sugars and healthy unsaturated fats, while limiting foods and drinks that are high in sugar, salt, and saturated fat^{39,40}. One study on two groups of patients having type-2 diabetes was evaluated how distinct diets impact metabolic control. One group was having unhealthy diet of refined carbohydrates, processed foods and sweet while other group was having healthy diet of whole carbohydrates, dairy, white meat, fish, fruits and vegetables. It demonstrates clear benefits from better food choices in achieving therapeutic targets for fasting plasma glucose, HbA1c, and LDL-cholesterol⁴¹.

Achieving and Maintaining a Healthy Weight

Excess body weight greatly increases type-2 diabetes risk. One study by Diabetes Prevention Program Research Group proved that high-risk individuals can lower this risk by 58% through modest lifestyle changes, including losing 7% of baseline weight through a healthy low-calorie, low-fat diet and getting 150 minutes or two and half hour of weekly physical activity such as brisk walking⁴².

Getting Screened Early / Early Detection

Since prediabetes and type-2 diabetes often develops silently with few or no noticeable symptoms, regular health screening is important, especially for people with risk factors such as overweight or obesity, a family history of diabetes, previous gestational diabetes, or increasing age⁸. Early detection allows lifestyle changes and treatment to begin before serious complications develop. Diagnosing diabetes early can protect the eyes, kidneys, heart, nerves, and blood vessels which help them to stay healthier.

Preventing Complications: Living Well with Diabetes:

Being diagnosed with diabetes does not mean that complications are inevitable. Good glycaemic control,

management of blood pressure and cholesterol, a healthy lifestyle, appropriate treatment, and regular medical follow-up can reduce the risk of developing diabetes-related complications^{4,8}.

Regular Health Checks

Many diabetes-related complications can develop without obvious symptoms in their early stages. Regular health checks therefore allow problems to be identified and treated earlier. People living with diabetes should undergo appropriate monitoring for eye disease, kidney disease and foot problems, together with assessment of blood glucose, blood pressure and cardiovascular risk factors^{4,8}.

Healthy Lifestyle

Maintaining a healthy body weight, following a balanced diet, remaining physically active and avoiding smoking are important components of diabetes management. Healthy lifestyle behaviours can improve glycaemic control and are associated with a lower risk of long-term complications⁴³. In some people with type-2 diabetes, substantial and sustained lifestyle changes together with appropriate medical care may result in diabetes remission⁴⁴.

Foot Care

People with diabetes, particularly those at increased risk of foot disease, should regularly inspect their feet for cuts, blisters, redness, swelling or other skin changes, wear appropriate footwear and seek prompt medical attention for wounds or signs of infection⁴⁵.

Smoking

Smoking further increases cardiovascular and other health risks in people with diabetes. Quitting smoking improves circulation, protects the heart and blood vessels, and one of the most important steps a person with diabetes can take to improve their long term. Smoking cessation is therefore an important part of reducing long-term cardiovascular risk^{46,47}.

Keep Blood Sugar, Blood Pressure, and Cholesterol Under Control

Maintaining healthy blood sugar levels is one of the most effective ways to reduce damage to the eyes, kidneys, nerves, heart, and blood vessels. Managing blood pressure and cholesterol are equally important because people with diabetes have a much higher risk of heart attack and stroke. Working with healthcare professionals to achieve these targets can significantly

reduce the risk of long-term complications^{2,8}.

Living well with diabetes is possible. By combining healthy lifestyle choices with regular medical care and following healthcare provider's advice, one can greatly reduce the risk of complications and continue to lead a healthy and active life.

CONCLUSION

Diabetes mellitus is a heterogeneous chronic metabolic disorder associated with significant morbidity and mortality. Understanding the mechanism or how type-1 and type-2 diabetes develop gives an opportunity to intervene before anything severe happens by early diagnosis, prevention, and appropriate management. Many cases of type-2 diabetes in high-risk individuals can be prevented or delayed through healthy or continued lifestyle modifications, weight management and appropriate medical care. Many people have no symptoms in the early stages, for which regular health screening is very important. The classical symptoms of diabetes include '3P's polydipsia (increased-thirst), polyuria (increased-urination) and polyphagia (increased-hunger). People with established diabetes

can still live a good quality of life through regular medical care and healthy daily habits. Good control of blood sugar, blood pressure, cholesterol, body weight, smoking, and cardiovascular and renal risk are essential to reduce complications. Routine screening for retinopathy, kidney disease, neuropathy, and diabetes-related foot disease enables complications to be detected before irreversible disability occurs. The life style modification with quality diet, discipline and drugs '3D's are the key principles of diabetic management. Every positive choice made today is an investment in a healthier tomorrow.

Conflict of interest

The authors have no conflict of interest to declare.

Authors contribution

All authors contributed to the conception and preparation of the manuscript, literature review, critical revision, and approval of the final version.

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