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Diabetes: a global challenge and the impact of melatonin

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Abstract

Diabetes mellitus, commonly referred to as diabetes, is a chronic metabolic disorder characterized by elevated blood sugar (glucose) levels. This abstract explores the different types of diabetes, their causes, and potential complications. It also highlights the global disease burden and the importance of management strategies. There are two main types of diabetes: type 1 and type 2. Type 1 diabetes is an autoimmune disease where the body attacks insulin-producing cells in the pancreas, leading to insulin deficiency. Type 2 diabetes, the most prevalent form, results from insulin resistance or impaired insulin secretion.

Gestational diabetes is a temporary form that develops during pregnancy. The primary cause of diabetes is a combination of genetic and environmental factors. While genetics play a role, lifestyle choices such as physical inactivity and unhealthy diet significantly contribute to the development of type 2 diabetes. Uncontrolled diabetes can lead to various complications affecting multiple organ systems. These include cardiovascular disease, neuropathy (nerve damage), nephropathy (kidney disease), retinopathy (eye disease), and foot ulcers, which can lead to amputation.

Diabetes is a global health problem with a rapidly growing prevalence. The increasing burden necessitates effective prevention and management strategies. These include lifestyle modifications, such as maintaining a healthy weight and engaging in regular physical activity, along with appropriate medication regimens and patient education. This abstract provides a concise overview of diabetes, highlighting its types, causes, potential complications, and the importance of tackling this global health challenge.

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Діабет: глобальна проблема та вплив мелатоніну

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Анотація

Цукровий діабет, який зазвичай називають діабетом, — це хронічне порушення обміну речовин, що характеризується підвищенням рівня цукру (глюкози) у крові. У цій анотації розглядаються різні типи діабету, їх причини та можливі ускладнення. Він також підкреслює глобальний тягар хвороб і важливість стратегій управління. Існує два основних типи діабету: тип 1 і тип 2. Діабет типу 1 – це аутоімунне захворювання, при якому організм атакує клітини підшлункової залози, що виробляють інсулін, що призводить до дефіциту інсуліну. Цукровий діабет 2 типу, найпоширеніша форма, виникає внаслідок резистентності до інсуліну або порушення секреції інсуліну.

Гестаційний діабет - це тимчасова форма, яка розвивається під час вагітності. Основною причиною діабету є поєднання генетичних факторів і факторів навколишнього середовища. Хоча генетика відіграє певну роль, вибір способу життя, наприклад відсутність фізичної активності та нездорове харчування, значно сприяє розвитку діабету 2 типу. Неконтрольований діабет може призвести до різноманітних ускладнень, що вражають різні системи органів. До них належать серцево-судинні захворювання, невропатія (пошкодження нервів), нефропатія (захворювання нирок), ретинопатія (захворювання очей) і виразки стопи, які можуть призвести до ампутації.

Діабет є глобальною проблемою охорони здоров'я, поширеність якої швидко зростає. Збільшення тягаря вимагає ефективних стратегій профілактики та управління. До них належать зміни способу життя, такі як підтримка нормальної ваги та регулярна фізична активність, а також відповідні режими лікування та навчання пацієнтів. Ця анотація містить стислий огляд діабету, висвітлюючи його типи, причини, потенційні ускладнення та важливість вирішення цієї глобальної проблеми охорони здоров'я.

Contents

Introduction

Diabetes mellitus (DM), commonly known as diabetes, is a chronic metabolic disorder characterized by elevated blood sugar (glucose) levels known as chronic hyperglycaemia resulting in disturbance in metabolism involving protein, carbohydrates and fats due to insulin resistance which mainly affects how the body utilizes glucose, a vital energy source for cells [2].

When glucose levels remain persistently

high, it can lead to serious health complications. There are approximately more than a billion patients suffering from chronic hyperglycaemia globally which is a significant public health issue. According to the estimates of the international diabetes federation, 537 million (10.5%) of adults aged 20–79 years are currently living with DM, and this may be expected to increase to 643 million (11.3%) by 2030 and 783 million (12.2%) by 2045.

Considering the 1.541 million adults with impaired glucose tolerance (IGT), their risk to develop type 2 diabetes is very high. The series of complications caused by diabetes may include blindness, renal failure, stroke, and coronary artery diseases, consequently, leading to a huge medical burden on society.

Moreover, diabetes costs at least 966 billion dollars in health expenditure, a 316% increase over the last 15 years [2]. The early stages of diabetes might go unnoticed, particularly in type 2 diabetes. However, as blood sugar levels become chronically elevated, several symptoms can emerge.

There are some common telltale signs e.g. frequent urination; elevated blood sugar levels can overwhelm the kidneys' ability to reabsorb glucose, leading to increased urination (polyuria), excessive thirst (polydipsia); frequent urination can deplete fluids, causing dehydration and increased thirst; unexplained weight loss; while initially weight loss might seem positive, in diabetes, the body might start breaking down muscle for energy due to insufficient glucose availability in cells, increased hunger (polyphagia); despite eating more, the body might struggle to utilize glucose for energy, leading to persistent hunger, fatigue and lethargy; chronic high blood sugar levels can impair the body's ability to convert glucose into energy, leading to exhaustion and a lack of energy, blurred vision; high blood sugar can affect the lenses in the eyes, causing blurry vision, slow-healing wounds; impaired blood flow and nerve damage associated with diabetes can make it harder for wounds to heal properly, frequent infections; higher infection rate is also common in prediabetic patients [3].

There are many vital aspects of management of the diabetes mellites. Health literacy is very important factor for the management and understanding of diabetes related complications.

Several tools for assessing health literacy were considered and are discussed in this review. This article delves into the different types of diabetes, their causes, potential consequences, and strategies for management and prevention.

I. Unveiling the Different Faces of Diabetes

Understanding the type of diabetes is crucial for proper management and treatment. There are three main types of diabetes;

1. Type 1 Diabetes

Type 1 diabetes, an autoimmune disorder, disrupts the body's natural ability to regulate blood sugar. Unlike type 2 diabetes, where the body either doesn't produce enough insulin or becomes resistant to its effects, type 1 is a more aggressive condition. It's characterized by the immune system mistakenly attacking the insulin-producing beta cells in the pancreas, leaving the body with very little or no insulin production. It typically manifests in childhood or young adulthood, though it can develop at any age. Individuals with type 1 diabetes face a lifelong challenge of managing their blood sugar levels through a combination of insulin therapy, diet, exercise, and ongoing monitoring [4].

The exact cause of type 1 diabetes remains a mystery, but scientists believe it's a result of a complex interplay between

genetics and environmental triggers. Having a close family member, like a parent or sibling, with type 1 diabetes significantly increases the risk. Specific gene variations can make an individual more susceptible. While the exact triggers are unknown, factors like viral infections or exposure to certain chemicals might play a role in susceptible individuals [5].

2. *Type 2 Diabetes*

This is the most prevalent form of diabetes, affecting around 90% of all cases. It arises due to either insulin resistance (cells become less responsive to insulin) or impaired insulin secretion by the pancreas. It disrupts the body's ability to regulate blood sugar (glucose) levels. Unlike type 1 diabetes, where the body lacks insulin production, type 2 presents a more complex interplay between insulin resistance and insufficient insulin secretion. This often develops gradually over time and can be significantly influenced by lifestyle choices. Genetic predisposition and lifestyle factors like physical inactivity and unhealthy diet are significant contributors [6].

3. *Gestational Diabetes*

This form of diabetes develops during pregnancy due to hormonal changes that can affect glucose metabolism. During pregnancy, the placenta produces hormones that help sustain the developing foetus. However, some of these hormones can also have an antagonistic effect on insulin, the hormone responsible for regulating blood sugar levels in the body. In some women, this hormonal shift leads to insulin resistance, causing blood sugar levels to rise. This temporary state is what defines gestational diabetes. While it typically resolves after childbirth, women with gestational diabetes have an increased risk of developing type 2 diabetes later in life [7].

4. *Maturity onset diabetes of the young (MODY)*

Maturity-onset diabetes of the young (MODY) is a genetic form of diabetes that often gets overshadowed by the more common type 1 and type 2 diabetes. Despite the name «maturity onset,» MODY typically presents before age 25, affecting 1-2% of all diagnosed diabetes cases. Understanding MODY is crucial for ensuring proper diagnosis and treatment for young people with diabetes.

Unlike type 1 diabetes, an autoimmune condition where the body attacks insulin-producing cells, MODY results from mutations in a single gene. This genetic defect disrupts the function of pancreatic beta cells, leading to insufficient insulin production. MODY also differs from type 2 diabetes, which is characterized by insulin resistance combined with potential insulin deficiency.

People with type 2 diabetes are often overweight or obese, whereas weight isn't a defining factor for MODY. Additionally, some MODY subtypes can be managed with medications other than insulin, unlike type 1 diabetes [8].

5. *Neonatal diabetes*

Neonatal diabetes mellitus (NDM) is a rare form of diabetes that strikes infants within the first 6 months of life. Unlike the more common type 1 and type 2 diabetes, NDM has a distinct cause and often requires specialized management. NDM is primarily a genetic condition. Unlike type 1 diabetes, which is an autoimmune disease, NDM arises from mutations in specific genes responsible for insulin production or function in the pancreas. These mutations can be inherited from one or both parents, or they can occur spontaneously in the child. There are over 30 known ge-

netic variations that can lead to NDM, with each one potentially influencing the development and treatment of the disease. NDM manifests in two main forms: transient and permanent. Transient NDM, affecting about half of all cases, typically resolves before the first birthday. However, there's a chance it might reappear later in life, often during teenage years. Permanent NDM, on the other hand, requires lifelong management with insulin therapy. Identifying the specific type of NDM is crucial for determining the appropriate treatment course [9].

6. *Wolfram Syndrome*

Wolfram syndrome, also known as DIDMOAD syndrome (an acronym for its four cardinal features), is a rare, progressive neurodegenerative disorder. It casts a long shadow, manifesting in childhood and gradually worsening over a lifetime. Wolfram syndrome is characterized by a quartet of primary symptoms: diabetes insipidus, diabetes mellitus, optic atrophy, and deafness. Diabetes insipidus arises from a malfunction in the pituitary gland, leading to excessive thirst and urination.

Diabetes mellitus, distinct from type 1 or 2 diabetes, results from the pancreas's inability to produce enough insulin. Optic atrophy signifies the degeneration of the optic nerve, causing progressive vision loss. Deafness, often sensorineural, can range from mild hearing loss to complete deafness.

The complexities of Wolfram syndrome extend beyond the core four symptoms. Many individuals experience additional neurological issues, including ataxia (imbalance and incoordination), slurred speech, and cognitive decline. Urinary tract problems, diabetes-related complications like neuropathy and nephropathy, and psychiatric issues like depression and anxiety can also be part of the picture.

The severity and order of symptom presentation can vary significantly, creating a unique journey for each person with Wolfram syndrome. Wolfram syndrome presents a formidable challenge, but with ongoing research, improved management strategies, and unwavering support, individuals with this condition can find ways to live fulfilling lives [10].

7. *Alström Syndrome*

Alström syndrome is a rare, genetic disorder that weaves a complex tapestry of symptoms across multiple organ systems. It presents a unique challenge for diagnosis and management, requiring a multifaceted approach to care. Alström syndrome exhibits a wide range of symptoms, often starting in childhood or adolescence. Cardinal features include progressive vision loss, sensorineural hearing impairment, kidney disease (nephropathy), and obesity or severe insulin resistance that can lead to type 2 diabetes. However, the syndrome extends beyond these core elements. Individuals may also experience cardiomyopathy (heart muscle weakness), liver dysfunction, skeletal abnormalities, and even intellectual disability. The specific combination and severity of symptoms can vary significantly from person to person, making Alström syndrome a highly individualistic condition. Alström syndrome is an autosomal recessive genetic disorder. This means a child needs to inherit two copies of the faulty gene, one from each parent, to develop the condition. Mutations in two specific genes, ALMS1 and ALMS2, have been identified as the primary culprits behind Alström syndrome. These genes are thought to play a crucial role in cellular processes like protein trafficking and ciliogenesis, the formation of hair-like structures on cells that are essential for various functions. When these genes are mutated, these processes fail, leading to the diverse symptoms observed in Alström syndrome [11].

8. *Latent Autoimmune diabetes in Adults (LADA)*

Latent autoimmune diabetes in adults (LADA), sometimes referred to as type 1.5 diabetes, occupies a unique space within the diabetes spectrum. It shares characteristics with both type 1 and type 2 diabetes, often leading to misdiagnosis. Understanding LADA is crucial for ensuring proper diagnosis and treatment for adults who develop this form of the disease. LADA, like type 1 diabetes, is an autoimmune disease. The body's immune system mistakenly attacks the insulin-producing beta cells in the pancreas. This gradual destruction leads to a decline in insulin production, causing the hallmark symptoms of diabetes – high blood sugar levels, increased thirst, frequent urination, and unexplained weight loss.

However, unlike the rapid onset of type 1 diabetes, often seen in childhood, LADA progresses slowly, typically developing in adults over 30 years old. While LADA shares some features with type 2 diabetes, there are key differences. Type 2 diabetes is primarily characterized by insulin resistance, where the body's cells become less responsive to insulin. People with type 2 diabetes often may still produce some insulin initially. In contrast, LADA involves a progressive decline in insulin production due to autoimmune destruction. Additionally, individuals with LADA may not be overweight or obese, a common risk factor for type 2 diabetes.

Diagnosing LADA can be challenging due to its slow onset and overlapping symptoms with other forms of diabetes. Blood sugar tests can confirm hyperglycemia, but additional tests are needed to differentiate LADA from type 1 and type 2 diabetes. Doctors may order tests for antibodies associated with the autoimmune attack on pancreatic beta cells, such as glutamic acid decarboxylase (GAD) antibodies [12].

9. *Type 3c diabetes*

Type 3c diabetes, also known as pancreatogenic diabetes or secondary diabetes, often gets overshadowed by its more common counterparts, type 1 and type 2 diabetes.

However, it's a distinct condition with its own set of causes, symptoms, and treatment approaches. Unlike type 1 diabetes, an autoimmune condition, and type 2 diabetes, characterized by insulin resistance, type 3c diabetes arises from damage or dysfunction of the pancreas itself. The pancreas plays a dual role in the body – producing digestive enzymes for food breakdown and secreting hormones, including insulin and glucagon, which regulate blood sugar levels. When the pancreas is compromised, its ability to produce these hormones can be impaired, leading to a decline in insulin and a potential rise in blood sugar.

While type 3c diabetes shares some symptoms with other forms of the disease, such as increased thirst, frequent urination, and unexplained weight loss, it has key distinguishing features. Unlike type 1 diabetes, which typically presents in childhood or adolescence, type 3c diabetes can develop at any age but often manifests in adults.

Additionally, individuals with type 3c diabetes may experience digestive issues like diarrhea, fatty stools, and abdominal pain due to the impaired production of digestive enzymes by the pancreas – a symptom not typically seen in type 1 or type 2 diabetes. Diagnosing type 3c diabetes involves a multi-pronged approach. Blood sugar tests will be used to assess for hyperglycemia. However, additional tests are often needed to differentiate it from other types of diabetes. Doctors may order tests to evaluate pancreatic function, such as fecal elastase or stool chymotrypsin, which measure digestive enzyme levels in the stool [13].

10. Steroid-induced diabetes

Steroid-induced diabetes, sometimes referred to as steroid hyperglycemia, is a condition that causes a temporary rise in blood sugar levels in individuals taking corticosteroids. While not a true form of diabetes like type 1 or type 2, it shares some similar symptoms and requires management to prevent complications. Corticosteroids are a class of powerful medications that mimic the effects of the hormone cortisol produced naturally by the adrenal glands.

They are widely used to treat various inflammatory conditions, such as asthma, rheumatoid arthritis, and autoimmune diseases like lupus. While corticosteroids offer significant therapeutic benefits for these conditions, they can also have side effects, including a temporary rise in blood sugar levels. The symptoms of steroid-induced diabetes can be subtle and easily missed, particularly in the early stages.

These may include increased thirst, urination, frequent urination, especially at night excessive hunger, unexplained weight loss, fatigue and feeling tired and blurred vision. Steroid-induced diabetes, while a temporary concern, requires careful management to prevent complications associated with chronic hyperglycaemia. By working closely with healthcare professionals and following the recommended treatment plan, individuals taking corticosteroids can navigate this condition effectively [14].

11. Cystic fibrosis diabetes

Cystic fibrosis (CF) is a complex genetic condition that primarily affects the lungs and digestive system. However, many individuals with CF also develop cystic fibrosis-related diabetes (CFRD), adding another layer of complexity to managing their health. Cystic fibrosis arises from mutations in the CFTR gene.

This gene plays a critical role in regulating the movement of salt and water across cell membranes in various organs, including the pancreas. In CF, these mutations lead to the production of thick, sticky mucus that clogs the airways and pancreatic ducts. The blocked pancreatic ducts prevent digestive enzymes from reaching the intestines, leading to digestive problems.

Additionally, the blockage can hinder the release of essential hormones produced by the pancreas, including insulin and glucagon, which regulate blood sugar levels [15].

II. Identification of risk factor for diabetes

The exact causes or risk factors of diabetes may vary depending on the type. However, both genetic and environmental factors play a role. Let's first discuss genetic factors briefly.

Genetic Predisposition

It is general agreement amongst the physicians that having a family history of diabetes increases the risk of developing Type 1 diabetes. Many studies have proposed that risk of developing T2D has a significant heritable component and support the notion that most of this inherited risk is associated with particular genotypic features and have identified several risk variants in genome-wide association studies, these variants still explain a relatively small proportion of the observed heritability. Genes can influence how the body produces or utilizes insulin [16].

Environmental Factors: Certain lifestyle choices significantly contribute to the development of type 2 diabetes, including, physical inactivity, unhealthy diet, obesity and smoking. A sedentary lifestyle reduces the body's ability to utilize

glucose effectively. Consumption of high-sugar, high-fat, and processed foods can impair insulin sensitivity. Excess weight, particularly abdominal fat, contributes to insulin resistance. Smoking can damage pancreatic beta cells and worsen insulin resistance [17].

The domino effect resulting from uncontrolled diabetes and its complications

Chronic hyperglycaemia (high blood sugar) can trigger a cascade of events leading to severe health complications. These include cardiovascular diseases, neuropathy, nephropathy, retinopathy, foot ulcers and amputations etc.

Diabetes significantly increases the risk of heart attack, stroke, and peripheral artery disease. High blood sugar can damage nerves throughout the body, causing pain, numbness, tingling, and weakness, particularly in the feet and legs. Diabetes is a leading cause of chronic kidney disease, which can eventually lead to kidney failure. Damage to the blood vessels in the retina can lead to vision problems, including blindness. Nerve damage and poor circulation in the feet can lead to foot ulcers, increasing the risk of amputation. These complications highlight the importance of maintaining good blood sugar control to prevent or delay their onset and progression [18].

Possible link between Melatonin, Diabetes and other Related Disorders

Melatonin influences day and night cycle, is produced by pineal gland. Synthetic melatonin drug is not approved by the US Food and Drug Administration for any purpose. It is confirmed that melatonin receptor agonists - ramelteon and tasimelteon are US Food and Drug Administration approved and are considered by the American Academy of Family Physicians for the treatment of sleep disorders. There are many medicines that consist melatonin, so it is possible to investigate effects of this hormone besides sleep control.

Nowadays, the most promising non-insomnia indications are for treating ischemia/reperfusion injury, primary headache disorders, fibromyalgia, glucose control, and blood pressure control. Most of the studies were preclinical and in in vivo and in vitro phases. More clinical trials are needed before recommending melatonin as a treatment in clinical practice [19].

Melatonin has adaptogenic properties that improve homeostasis. Nowadays many authors consider that melatonin production is influenced the appearance and development of osteoporosis in postmenopausal period. Administration of melatonin is effective for bone tissue restoration and rise skeletal strength. Melatonin could prevent and be useful in treatment of postmenopausal osteoporosis, according to its biological effects.

Level of melatonin in blood plasma is considered to bone tissue, the determination of which is one of the methods for the diagnostic of osteoporosis. Melatonin has a big influence on bone restoring by stimulating osteogenesis and suppressing osteoclasts action. Melatonin controls the biological rhythm of bone tissue, which improves its osteogenic effect. Besides, melatonin takes place in the modulation of the bone microenvironment. Melatonin decreases the damage induced by oxidative stress and inflammation on osteoblasts and prevents osteolysis from reactive oxygen species and inflammatory agents.

As an addition drug against osteoporosis, melatonin can improve the gut microflora, remodel microbiota composition, regulate substance absorption and keep metabolic balance, all of which are beneficial for the health of bone tissue. This all taken into account, demonstrates the effects of melatonin on bone metabolism. So, melatonin could be important for the diagnostic, prevention and medication of

postmenopausal osteoporosis [20].

Melatonin is a sleeping hormone from the pineal gland that released in the dark and suppressed during the day. Melatonin has interactions with insulin. There are evidences, that melatonin has positive effect in the treatment of diabetes mellitus (DM). Elevated production of free radicals is a characteristic of DM associated with diabetic neuropathy, retinopathy, nephropathy and cardiovascular disorders.

Reactive oxygen species are produced in big amounts in reactions of glucose and lipid peroxidation, caused diabetic complications.

These events influence the biomolecules and activate apoptosis. Melatonin has antioxidative properties, mitigates oxidative stress caused by free radical reactions. Additionally, melatonin injection is believed to have other antidiabetic influences such as decreasing cellular apoptosis and enhancing the production of antioxidants [21].

III. Investigations of melatonin effects in diabetes mellitus conditions

It is necessary to control the concentration of glucose in the blood to prevent complications in patients with diabetes. Melatonin and its metabolites have powerful antioxidant/anti-inflammatory properties. To determine the effect of melatonin on the level of glucose, the content of malondialdehyde (MDA), the activities of the enzymes pyruvate kinase and glucose-6-phosphate dehydrogenase (G6PDH) were measured in the blood of rats with impaired glucose tolerance (PTG).

The research was carried out in accordance with the bioethics of examination of preclinical and other scientific research conducted on animals (Kyiv, 2006). Diabetes mellitus was induced by intraperitoneal administration of 5% solution of alloxan monohydrate at the rate of 170 mg/kg of rat body weight. Four days after the induction of diabetes, rats were divided into a group of animals with impaired glucose tolerance (fasting plasma glucose <5.6 mmol/L; postprandial glycemia (2 hours after exercise) 7.8–11.0 mmol/L)) and a group of animals with PTH receiving injections of melatonin (5 mg/kg «Sigma» USA, daily and intraperitoneally for 42 days, starting on the 5th day).

Statistical analysis was performed using Statistica 10 StatSoft Inc. Injections of melatonin caused a normalization of the serum glucose profile of animals with PTH compared to the corresponding values before treatment. According to our results, the activities of pyruvate kinase in erythrocytes of animals with PTH decreased by 18%, while the activity of G6PDH increased by 35% respectively compared to the control (intact).

The level of MDA was 23% higher in the group of rats with PTH than in the control group. Melatonin prevented the diabetes-induced increase in MDA levels in the blood of PTH rats. We achieved restoration of pyruvate kinase and normalization of G6PDH activities in the blood of rats with PTH using melatonin injections.

Perhaps this is explained by the fact that the pro- and antioxidant components, as well as the concentration of glucose in the blood after melatonin treatment are equalized: glucose enters the peripheral tissues through open glucose channels, damage to the β-cells of the islets of Langerhans is stopped by the activation of the glutathione system of antioxidant protection. We determined that long-term melatonin injections improved glucose tolerance in alloxan diabetic rats [22,23].

Interesting are investigations about influence of melatonin in a dose of 10 mg of body weight daily on energy metabolism in diabetic rats. In the liver of rats with DM, under the conditions of equinox, activities of G-6-PDH, 6-PGDH and TK decreased by 42, 32 and 40% respectively compared to control. The activities of G-6-PDH, 6-PGDH

in animals with latent diabetes were 77 and 64% higher respectively than in control ones. In the liver of animals that were under conditions of constant darkness, the activities of G-6-PDG, 6-PGDH and TK increased by 38, 29, and 12% respectively while under conditions of constant light these indicators decreased by 18, 10 and 15% respectively in comparison with control.

In animals with DM under conditions of constant darkness the activities of G-6-PDG, 6-PGDH and TK increased by 32, 22 and 19% respectively; under conditions of constant light – decreased by 34, 17 and 28% respectively compared to the control. With constant darkness against the background of latent diabetes, the activities of G-6-PDG, 6-PGDH and TK increased by 115, 95 and 30%, respectively; under conditions of constant light they were 24, 16, and 22% lower respectively than control.

Administration of melatonin to animals with DM led to:

1) an increase in the activity of G-6-PDH, 6-PGDH, and TK by 40, 31, and 25% respectively compared to the parameters of control;

2) normalization of the indicated parameters under conditions of constant darkness;

3) an increase in the activities of G-6-PDH, 6-PGDH, and TC by 140, 123, and 60% respectively compared to the control, under conditions of constant light. In animals with latent diabetes under the influence of melatonin in all types of illuminations, the specified indicators were normalized (except for the activity of G-6-PDH under conditions of constant light that increased by 20% compared to control).

So, the introduction of melatonin at a dose of 10 mg/kg of weight contributed to the restoration of the amphibolic and energetic function of the pentose phosphate pathway of glucose-6-phosphate oxidation under the conditions of diabetes on the background of a changed photoperiod [22].

A Global Challenge: The Rising Tide of Diabetes

Diabetes has become a global health epidemic. According to the International Diabetes Federation (IDF), approximately 463 million people worldwide live with diabetes in 2019, with a projected rise to 700 million by 2045.

This alarming increase is attributed to various factors, including ageing population, urbanization, life style changes, and increased obesity rates.

As populations age, the risk of diabetes increases. Urbanization often leads to sedentary lifestyles and unhealthy dietary patterns. The global rise in obesity rates is a significant contributor to type 2 diabetes.

The economic burden of diabetes is also substantial. The IDF estimates the global cost of diabetes at $760 billion in 2019 [24].

IV. Taking Control: Management Strategies for Diabetes

Fortunately, diabetes is a manageable condition. Effective management strategies can help control blood sugar levels and prevent complications. These include:

Lifestyle Modifications:

Maintaining a healthy weight through a balanced diet and regular physical activity is crucial for managing all types of diabetes.

Dietary strategies include consuming plenty of fruits, vegetables, whole grains, and lean protein while limiting sugary drinks, refined carbohydrates, and unhealthy fats [25].

Medication:

Type 1 diabetes requires lifelong insulin therapy to replace the missing insulin. Type 2 diabetes management may involve various medications depending on individ-

ual needs, such as oral medications like metformin that improve insulin sensitivity or injectable medications like GLP-1 receptor agonists that stimulate insulin secretion and slow down food absorption. Gestational diabetes may be managed through lifestyle modifications alone or may require medication like insulin to maintain healthy blood sugar levels during pregnancy [26].

Blood Sugar Monitoring:

Regularly monitoring blood sugar levels at home allows individuals to adjust their diet, medication, and physical activity as needed to maintain optimal control.

Patient Education:

Empowering individuals with diabetes knowledge about the disease, treatment options, and healthy lifestyle choices is crucial for self-management and preventing complications.

Additional tools that assess patients' reading ability include the Rapid Estimate of Adult Literacy in Medicine (REALM) and the Literacy Assessment for Diabetes.

Tests that assess diabetes numeracy skills include the Diabetes Numeracy Test, the Newest Vital Sign (NVS), and the Single-Item Literacy Screener (SILS) [27].

V. Discussion and conclusion

Rates of both diabetes and low health literacy are higher in populations from low socioeconomic backgrounds. People living in disadvantaged communities face many barriers when seeking health care, including inconsistent housing, lack of transportation, financial difficulties, differing cultural beliefs about health care, and mistrust of the medical professions.

People with high rates of medical mistrust tend to be less engaged in their care and to have poor communication with HCPs, which is another factor HCPs need to address when working with their patients with diabetes. The cost of medical care for people with diabetes was $327 billion in 2017, a 26% increase since 2012.

Many of these medical expenditures are related to hospitalization and inpatient care, which accounts for 30% of total medical costs for people with diabetes. People with diabetes also may neglect self-management tasks for various reasons, including low health literacy, lack of diabetes knowledge, and mistrust between patients and HCPs.

These challenges can be even more pronounced in vulnerable populations because of language barriers and patient-provider mistrust. Rates of diabetes are higher among racial and ethnic minority groups; 15.1% of American Indians and Alaskan Natives, 12.7% of Non-Hispanic Blacks, 12.1% of Hispanics, and 8% of Asian Americans have diagnosed diabetes, compared with 7.4% of non-Hispanic Whites.

Additionally, patient-provider relationship deficits can be attributed to challenges with communication, including HCPs' lack of attention to speaking slowly and clearly and checking for patients' understanding when providing education or gathering information from people who speak English as a second language demonstrated that patients with higher provider mistrust felt that their provider's communication style was less interpersonal and did not feel welcome as part of the decision-making process [28]. Living with a chronic condition like diabetes can be stressful. Counselling and support groups can help individuals cope with the emotional challenges and maintain healthy behaviours.

While type 1 diabetes cannot be prevented, there are significant opportunities to prevent type 2 diabetes and gestation-

al diabetes through lifestyle modifications, maintaining a healthy weight, healthy eating and regular physical activity. Losing weight or maintaining a healthy body weight can significantly reduce the risk of type 2 diabetes.

Adopting a balanced diet rich in fruits, vegetables, whole grains, and lean protein while limiting unhealthy fats, processed foods, and sugary drinks promotes healthy blood sugar levels. Engaging in regular physical activity, such as brisk walking or cycling for at least 30 minutes most days of the week, improves insulin sensitivity and helps control blood sugar.

Maintaining a healthy weight before and during pregnancy, consuming a balanced diet, and exercising regularly can significantly reduce the risk of gestational diabetes. Diabetes is a complex and multifaceted challenge [29].

Effective management strategies, including lifestyle modifications (sleep and awake cycle), medication, and ongoing support, individuals with diabetes can live long and healthy lives. Public health initiatives focused on promoting healthy lifestyles, early diagnosis, including measurement of melatonin levels and access to quality care are crucial for tackling this global health epidemic.

By working together, we can empower individuals with diabetes and prevent the disease from impacting future generations.

Conflict of interest

The authors declare no financial or other conflicts of interest that could affect the results, interpretation and conclusions of the study.

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