A Review of Experimental Animal Models Used in Diabetes Research

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Abstract
Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from impaired insulin secretion, insulin resistance, or a combination of both. Owing to its rising global prevalence and associated microvascular and macrovascular complications, there is an increasing demand for safe, effective, and affordable therapeutic strategies. Experimental animal models play a pivotal role in diabetes research by enabling the investigation of disease mechanisms, pathophysiological changes, and the preclinical evaluation of antidiabetic agents. This review provides a comprehensive overview of the major experimental animal models of diabetes, encompassing chemically induced, diet-induced, genetically modified, and combined models. Each model offers distinct advantages in mimicking specific aspects of type 1 or type 2 diabetes, such as beta-cell destruction, insulin resistance, obesity, and diabetic complications. The utility of these models in antidiabetic drug discovery, mechanistic studies, and pharmacological evaluation is critically discussed, along with their limitations in translating findings to human disease. A clear understanding of the strengths and limitations of each model is essential for appropriate model selection in preclinical research and for the development of novel therapeutic interventions for diabetes mellitus.

Keywords: Diabetes Mellitus; Animal Models; Antidiabetic Activity; Oxidative Stress; Insulin resistance; Diabetic complications.

Introduction

Diabetes mellitus is a complicated and long-lasting metabolic condition which appears as itself by the continuous elevation of blood sugar levels. This happens because of the issues in either the production of insulin, the usage of insulin, or both. It is considered as one of the biggest health threats globally due to its fast-growing number of cases, and the difficulties that come and it. Based on today's health statistics studies, the affected population by this disease has much increased for the last few decades, and that has In fact made this disease one of the main causes of death and illness worldwide[1]. Factors like inactive lifestyle, improper eating habits overweight migration to urban environment, increase in age, and genetic susceptibility have been considered as the causes of the ever-expanding problem of diabetes. If the disease is not controlled, it may bring about harsh consequences, which can extend to different parts of the body that may include heart trouble, kidney failure, nerve damage, eye impairment, and delay in skin healing. This will result in additional social and economic difficulties for the already almost overwhelmed health institutions[2].

Diabetes mellitus covers a diverse range of disorders and is generally divided into T1DM, T2DM, GDM and other specific types due to genetic variations, hormonal imbalances, or drug-related conditions. T1DM is the result of an immune reaction which destroys pancreatic -cells leading to the total lack of insulin, However T2DM is mostly related to the cells' inability to respond to insulin and the gradual deterioration of the cells[3]. T2DM is the cause of about 90-95% of the total number of diabetes cases and it is deeply connected with obesity and factors related to lifestyle habits. Even though these diseases are different in their causes, they all have in common that the body cannot

properly manage the sugar levels and the risk of the complications that appear after a long time is growing[4].

Throughout the last decades, tremendous efforts have been made to enhance the development of antidiabetic drugs, like insulin formulations sulfonylureas biguanides, thiazolidinediones, -glucosidase inhibitors, DPP-4 inhibitors, GLP-1 receptor agonists, and SGLT2 inhibitors. Despite really these treatment options have led to better glycemic control and patient outcomes, the side effects of these medications are a major concern[5]. Numerous antidiabetic drugs potentially induce adverse effects such as hypoglycemia, gastrointestinal disturbances, weight gain, fluid retention, and cardiovascular issues. Besides, the long-term therapy may turn out to be very expensive, and it may not effectively avert the progression of the disease or the incidence of diabetic complications[6]. Compliance with the prescribed medications is frequently compromised as patients have to take medication for their lifetime, and the treatment regimens are complicated. So, these issues have stimulated investigators to consider other therapeutic approaches which are effective safe inexpensive, and target multiple mechanisms of the disease at the same time[7]. In this article, we will comprehensively review the existing research onanimal experimental diabetes models.

Overview of Diabetes Mellitus

DM is a chronic metabolic disorder that is marked by the presence of continuous hyperglycemia resulting from the body's inability to produce insulin, the improper use of insulin, or a combination of the two[8]. It is among the leading non-communicable diseases worldwide and creates a major challenge to public health systems due to its rising incidence and the complications that accompany it. Under normal conditions, the levels of glucose in the blood are kept stable through the joint actions of insulin and other metabolic hormones. In diabetes, the failure of these regulatory processes leads to high blood sugar levels, changes in the metabolism of carbohydrates, lipids, and proteins, as well as gradual harm to multiple organs[9], [10].

Type 1 diabetes mellitus is an autoimmune disease in which the insulin-producing -cells of the pancreatic islets of Langerhans are selectively destroyed. Besides genetic predisposition, environmental factors and immune dysfunction play roles in the development of the disease. People with certain HLA genes have a higher likelihood of developing T1DM. Environmental factors like viral infections, various dietary components, and toxins might trigger the immune system to produce antibodies against -cell antigens[11]. Lymphocytes of the T type, once activated, enter the pancreatic islets and cause inflammation and damage by releasing cytokines and substances that kill cells. As more and more -cells get destroyed, there is a significant loss of insulin production which means that glucose will not be taken up adequately by the cells of the body and, at the same time, the liver will continue to produce glucose in excess. Without insulin, the breakdown of fat (lipolysis) and the formation of ketone bodies (ketogenesis) are facilitated and the patient becomes susceptible to diabetic ketoacidosis. Most of the times, the onset of the disease is marked by symptoms like excessive urination, increased thirst and hunger, weight loss, fatigue, and high blood sugar level. Because the body is barely producing any insulin, the patients have to undergo insulin replacement therapy for the rest of their lives[12].

T2DM is a metabolic disorder involving a combination of insulin resistance and progressive pancreatic -cell failure. Unlike T1DM, T2DM usually evolves over a long period of time. It is commonly seen in individuals who are overweight or obese, not physically active, getting older, and have a family history of the condition[13]. During the initial phase, tissue cells namely muscles, fat cells, as well as liver cells become refractory to the action of insulin, resulting in decreased glucose uptake and increased glucose production by the liver. To offset insulin resistance, the insulin-secreting cells in the pancreas ramp up production. But, after extended periods of excessive functional demand, the insulin-secreting cells undergo functional decline and loss. Other factors that influence the pathogenesis of diabetes are chronic inflammation, oxidative stress, abnormal secretion of adipokines, and mitochondrial dysfunction. Hyperglycemia and dyslipidemia are perpetuating factors that will lead to -cell failure and diabetic complications[14].

Insulin resistance is an intrinsic feature of T2DM and is defined as an impairment in the usual biological response of target tissues to normal concentrations of circulating insulin. The pathogenesis is complex with a number of factors contributing to insulin resistance including obesity mediated increased free fatty acids inflammation mitochondrial dysfunction and abnormalities in insulin receptor signaling cascades[15]. Adipose tissue from the obese overexpresses pro-inflammatory cytokines including TNF-α and IL-6 which antagonize insulin receptor signaling and impede glucose transport. As cellular

sensitivity to insulin deteriorates, pancreatic islet -cells respond by increasing insulin output, Because of this maintaining a euglycaemic state. Chronic increased glucose concentrations and increased lipids levels together induce a toxic cell environment, which causes oxidative and endoplasmic reticulum stress and apoptosis and finally loss of -cell-cell communication. The progressive decline in -cell number and function leads to a relative insulin deficiency and T2DM progresses[16].

Oxidative stress and Inflammation in Diabetes Both oxidative stress and chronic low grade inflammation are proven to be central in both the pathogenesis and progression of diabetes and its associated complications[17]. Hyperglycemia results in the overproduction of ROS, caused by numerous mechanisms including autooxidation of glucose, non-enzymatic protein glycosylation and mitochondrial derangements. Overproduction of ROS can cause widespread cellular damage and loss of normal metabolic regulation, which in turn can result in beta cell dysfunction as pancreatic -cells are very sensitive due to their relative lack of antioxidant defenses[18], [19].

Persistent hyperglycemia can cause a wide spectrum of microvascular complications (diabetic microangiopathies such as retinopathy, nephropathy and neuropathy) as well as macrovascular complications (including accelerated atherogenesis leading to coronary artery, cerebrovascular disease and peripheral occlusive disease)[20]. Oxidative stress can contribute to the development of these complications as can diabetes-associated biochemical abnormalities in lipid, carbohydrate and protein metabolism. Additional diabetes-related complications include seriously impaired wound healing, increased infection susceptibility, hepatic dysfunction and cognitive impairment and efforts to prevent and treat these diabetes-related changes need to aim to improve glycemia as well as to control these concomitant processes (Figure.1)

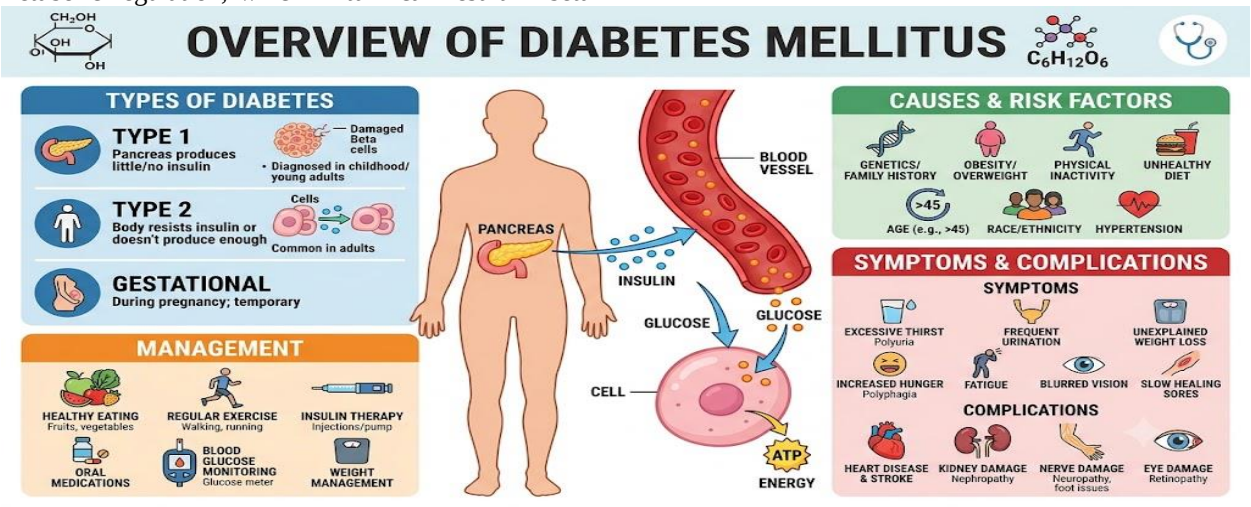

Figure.1: Overview of diabetes mellitus: types, mechanisms, risk factors, symptoms, complications, and treatment.

Animals Models of Diabetes Mellitus

Large animal models serve as an essential bridge between rodent studies and human clinical trials because they closely replicate human anatomy, physiology, pancreatic architecture, glucose metabolism, and the progression of diabetic complications [21],[22]. Among these, pigs, dogs, non-human primates, sheep, goats, and rabbits are widely employed to investigate the pathogenesis of both type 1 and type 2 diabetes mellitus and to evaluate emerging therapeutic strategies [23]. Diabetes in these animals can be induced through chemical agents such as streptozotocin (STZ) and alloxan [24], dietary interventions including high-fat or Western diets [25], surgical procedures such as pancreatectomy [26], or genetic modifications that reproduce inherited forms of diabetes [27]. Pig models, particularly Ossabaw pigs, Göttingen minipigs, and Yucatan minipigs**,** are highly valued due to their close resemblance to human metabolic and cardiovascular physiology, making them ideal for studies involving islet transplantation, artificial pancreas development, and metabolic disorders [28]. Canine models have historically contributed to insulin replacement and glucose-monitoring research, whereas non-human primates provide the highest translational relevance for studying

obesity-associated type 2 diabetes, β-cell dysfunction, immunology, and regenerative therapies despite their high cost and ethical constraints [29]. Sheep models are primarily used to investigate gestational diabetes and fetal metabolic programming, while goat and rabbit models are useful for endocrine physiology, vascular complications, and biomarker research [30]. Although large animal models require specialized facilities, higher maintenance costs, and strict ethical oversight, they remain indispensable for validating preclinical findings, assessing long-term safety and efficacy of antidiabetic interventions, and facilitating the translation of novel therapies into clinical practice. Also, they reveal gene-environment interactions and how the disease evolves (Table.1).

Table 1: Animal Models of Diabetes Mellitus: Characteristics, Advantages, and Applications

Model Category	Specific Model	Method of Induction	Key Features	Advantages	Limitations	Common Applications
Chemically Induced	Streptozotocin (STZ) Model	Single or multiple STZ injections	Selective β-cell destruction, severe hyperglycemia	Rapid, reproducible, widely used	Limited insulin resistance component	Antidiabetic drug screening, β-cell protection studies
Chemically Induced	Alloxan Model	Alloxan administration	ROS-mediated β-cell necrosis	Simple and inexpensive	Variable susceptibility among animals	Evaluation of hypoglycemic agents
Chemically Induced	Nicotinamide-STZ Model	Nicotinamide followed by STZ	Partial β-cell damage, residual insulin secretion	Mimics moderate diabetes	Variability in induction protocols	Testing insulin sensitizers and phytochemicals
Diet-Induced	High-Fat Diet (HFD) Model	Long-term high-fat feeding	Obesity, insulin resistance, hyperinsulinemia	Closely resembles lifestyle-induced diabetes	Requires prolonged feeding period	Metabolic syndrome and obesity research
Diet-Induced	High-Fat High-Sucrose Diet Model	Fat- and sugar-rich diet	Insulin resistance, dyslipidemia, hepatic steatosis	Mimics Western dietary habits	Variable severity among strains	Nutritional intervention studies
Diet-Induced	Non-Obese Diabetic (NOD) Model	Spontaneous autoimmune β-cell destruction.	Autoimmunity, insulin deficiency, persistent hyperglycaemia.	Closely mimics human T1DM pathogenesis	Variable onset; female predominance only	Autoimmunity, immunotherapy, transplantation, β-cell studies

Genetic	db/db Mouse	Leptin receptor mutation	Obesity, severe insulin resistance, hyperglycemia	Spontaneous disease development	Expensive maintenance	Drug efficacy and mechanistic studies
Genetic	ob/ob Mouse	Leptin deficiency mutation	Hyperphagia, obesity, insulin resistance	Well-characterized model	Less severe β-cell failure	Obesity and insulin resistance research
Genetic	Zucker Diabetic Fatty (ZDF) Rat	Leptin receptor mutation	Obesity, insulin resistance, progressive diabetes	Closely mimics human T2DM progression	High maintenance cost	Antidiabetic and metabolic studies
Combination	HFD + Low-Dose STZ Model	High-fat diet followed by low-dose STZ	Insulin resistance and β-cell dysfunction	Highly translational	Protocol variability	Most commonly used T2DM model
Streptozotocin (STZ)-Induced Pig Model	Pig (Sus scrofa)	Intravenous or intraperitoneal STZ administration causing β-cell destruction	Persistent hyperglycemia, insulin deficiency, impaired glucose tolerance	Anatomy, physiology, pancreatic structure, and cardiovascular system closely resemble humans	Variable sensitivity to STZ, expensive maintenance, intensive monitoring	Islet transplantation, artificial pancreas, insulin delivery systems, diabetic complications
Alloxan-Induced Pig Model	Pig	Alloxan selectively destroys pancreatic β-cells via oxidative stress	Type 1 diabetes-like phenotype with severe insulin deficiency	Rapid induction and reproducibility	High mortality, nephrotoxicity, inconsistent diabetes induction	β-cell regeneration, insulin therapy, transplantation studies
Pancreatectomized Pig Model	Pig	Partial or total surgical removal of	Complete insulin deficiency and severe	Stable diabetic state, no chemical toxicity	Highly invasive surgery, postoperative	Islet transplantation, endocrine pancreas research,

		pancreas	hyperglycemia		complications	metabolic surgery
Genetically Modified Pig Models	Pig	CRISPR/Cas9 or transgenic modification (e.g., INS mutation, HNF1A mutation)	Heritable diabetes with progressive β-cell dysfunction	Closely mimics human genetic diabetes; useful for precision medicine	High cost, long breeding cycles, ethical concerns	Gene therapy, diabetes genetics, regenerative medicine
Ossabaw Pig Model	Ossabaw pig	High-fat, high-calorie "Western diet"	Obesity, insulin resistance, dyslipidemia, metabolic syndrome, Type 2 diabetes	Naturally develops metabolic syndrome similar to humans	Long induction period; specialized breed availability	Type 2 diabetes, obesity, NAFLD, cardiovascular disease
Yucatan Miniature Pig Model	Miniature pig	High-fat/high-sucrose diet ± STZ	Obesity, insulin resistance, moderate β-cell dysfunction	Easier handling than domestic pigs; suitable for imaging	Longer disease induction; higher maintenance costs	Drug development, metabolic imaging, bariatric surgery
Göttingen Minipig Model	Minipig	High-fat diet, STZ, or genetic manipulation	Hyperglycemia, insulin resistance, obesity	Small body size, standardized genetics, good translational relevance	Expensive animal purchase and husbandry	Pharmacokinetic studies, toxicology, diabetes therapeutics
Diet-Induced Diabetic Dog Model	Dog (Beagle or mixed breeds)	High-fat/high-energy diet with reduced activity	Obesity, insulin resistance, impaired glucose tolerance	Similar glucose metabolism and lipid profile to humans	Ethical restrictions and public concern	Anti-diabetic drug evaluation, metabolic syndrome research
STZ-Induced Dog Model	Dog	Intravenous STZ administration	Severe insulin deficiency resembling Type 1	Well-characterized physiology and cardiovascular	Nephrotoxicity, variable response, ethical	Insulin replacement studies, transplantation, glucose

			diabetes	similarities	considerations	monitoring devices
Pancreatectomized Dog Model	Dog	Surgical pancreatectomy	Stable insulin-dependent diabetes	Predictable diabetic phenotype; useful for metabolic studies	Surgical expertise required; lifelong insulin support	Islet transplantation, artificial pancreas development
Spontaneous Diabetic Dog	Dog	Naturally occurring autoimmune diabetes	Hyperglycemia, insulin dependence, diabetic cataracts	Closely resembles human Type 1 diabetes in clinical progression	Genetic variability and limited availability	Comparative endocrinology, veterinary diabetes, translational studies
Diet-Induced Non-Human Primate Model	Rhesus macaque, Cynomolgus monkey	High-fat/high-sugar diet and aging	Obesity, insulin resistance, hyperinsulinemia progressing to Type 2 diabetes	Highest physiological similarity to humans	Extremely expensive, ethical limitations, long study duration	Pathophysiology, biomarker discovery, therapeutic testing
Spontaneous Diabetic Non-Human Primates	Rhesus macaque, Baboon	Naturally develops diabetes with aging	Progressive insulin resistance, β-cell dysfunction, dyslipidemia	Mimics natural progression of human Type 2 diabetes	Limited availability and high maintenance costs	Longitudinal diabetes studies, aging research
STZ-Induced Non-Human Primate Model	Rhesus macaque, Cynomolgus monkey	STZ-mediated β-cell destruction	Stable insulin-dependent diabetes	Excellent translational relevance for immunology and transplantation	Ethical constraints and specialized facilities required	Islet transplantation, stem cell therapy, immunosuppression studies
Baboon Metabolic Syndrome Model	Baboon	High-fat diet with genetic susceptibility	Obesity, insulin resistance, hypertension, dyslipidemia	Human-like cardiovascular and metabolic physiology	High cost and limited research colonies	Cardiometabolic disease, diabetic vascular complications
Sheep Model of	Sheep	Maternal	Maternal	Ideal for fetal	Less	Gestational

Gestational Diabetes		overnutrition, glucocorticoid exposure, or glucose infusion	hyperglycemia, fetal metabolic programming	physiology and placental studies	suitable for chronic adult diabetes research	diabetes, fetal development, developmental programming
Goat Diabetic Model	Goat	STZ or alloxan administration	Hyperglycemia, hypoinsulinemia	Large blood volume facilitates repeated sampling	Limited standardized protocols	Endocrine physiology, biomarker studies
Rabbit Diabetic Model	Rabbit	Alloxan, STZ, cholesterol-rich diet	Hyperglycemia with accelerated atherosclerosis	Excellent model for diabetic vascular disease	Greater susceptibility to chemical toxicity	Diabetic nephropathy, retinopathy, atherosclerosis, wound healing

Chemically induced models are fast, cheap, and very reproducible but they can't capture the progressive aspect of human diabetes completely. Diet induced models simulate very well the insulin resistance connected to obesity, but they need longer periods of induction. However, genetic models are great for understanding the mechanisms of the disease and identifying the potential complications but they are normally quite expensive and to some extent limited by the differences between species[21]. The combination models, mainly the HFD-STZ model, are viewed as the most clinically relevant among the models as they simulate the insulin resistance and the -cell dysfunction at the same time, which are the main factors of human type 2 diabetes. So, the selection of a research model should show data goals, pathological features to be studied and the extent of human diabetes that the model will be relevant to (Figure.2).

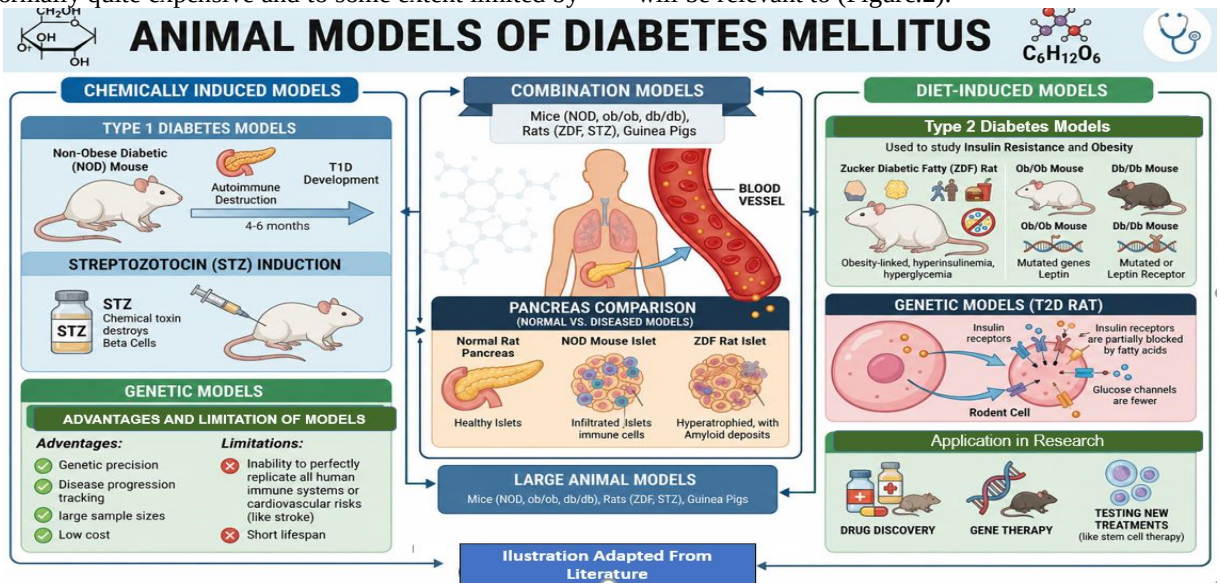

Figure.2: Animal models of diabetes mellitus: major categories, key mechanisms, and representative research applications..

Conclusion

In diabetes research, animal models are still essential because they offer a controlled and repeatable platform for examining the pathophysiology of the illness, assessing potential antidiabetic treatments, and tracking the development of both acute and chronic problems. Different characteristics of type 1 and type 2 diabetes are replicated by chemically induced, diet-induced, genetic, and combination models; however, none of these models completely capture the complexity of the human illness. Therefore, the particular scientific goal, the diabetic phenotype of interest, and the translational significance of the experimental design should all be taken into consideration when choosing an acceptable model. Animal models are nevertheless essential for preclinical diabetes research and the logical development of new treatment approaches, despite their inherent drawbacks**.**

References

1. Elechi NA, Ewelike FW. Antidiabetic Activity of Fractions of the n-Hexane Extract of Leaves of *Eriosema psoraleoides* (Lam) G. Don (Leguminosae) on Alloxan-induced Diabetic Albino Rats. Indian Journal of Pharmaceutical and Biological Research 2019;7(04):05-9.
2. Clemente-Suárez, V.J., et al., The impact of the COVID-19 pandemic on social, health, and economy. Sustainability, 2021; 13(11): 6314.
3. McKay, G., et al., A century of insulin: from lifesaving discovery to a journey of scientific evolution! Practical Diabetes, 2021; 38(4): 7-12.
4. Awuchi, C.G., C.K. Echeta, and V.S. Igwe, Diabetes and the nutrition and diets for its prevention and treatment: a systematic review and dietetic perspective. Health Sciences Research, 2020;6(1): 5-19.
5. Cohen, A. and E.S. Horton, Progress in the treatment of type 2 diabetes: new pharmacologic approaches to improve glycemic control. Current medical research and opinion, 2007;23(4) 905-917.
6. Religioni, U., et al., Enhancing therapy adherence: impact on clinical outcomes, healthcare costs, and patient quality of life. Medicina, 2025; 61(1): 153.
7. Bashor, C.J., et al., Engineering the next generation of cell-based therapeutics. Nature Reviews Drug Discovery, 2022; 21(9): 655-675.
8. Bastaki, S., Diabetes mellitus and its treatment. International journal of Diabetes and Metabolism, 2005;13(3): 111-134.
9. Rahman, M.S., et al., Role of insulin in health and disease: an update. International journal of molecular sciences, 2021; 22(12): 6403.
10. Singh, H., et al., Role of oxidative stress in diabetes-induced complications and their management with antioxidants. Archives of Physiology and Biochemistry, 2024;130(6):616-641.
11. Dotan, A. and Y. Shoenfeld, Autoimmunity on the Rise: COVID-19 as a Trigger of Autoimmunity, in Infection and Autoimmunity. 2024, Elsevier. p. 247-257.
12. Kumar, R., et al., A review on diabetes mellitus: type1 & Type2. World Journal of Pharmacy and Pharmaceutical Sciences, 2020;9(10):838-850.
13. Williams, E.P., et al., Overweight and obesity: prevalence, consequences, and causes of a growing public health problem. Current obesity reports, 2015;4(3): 363-370.
14. Varra, F.-N., et al., Molecular and pathophysiological relationship between obesity and chronic inflammation in the manifestation of metabolic dysfunctions and their inflammation -mediating treatment options. Molecular medicine reports, 2024;29(6):95.
15. Chandrasekaran, P. and R. Weiskirchen, Cellular and molecular mechanisms of insulin resistance. Current Tissue Microenvironment Reports, 2024; 5(3):79-90.
16. Ghemrawi, R., S.-F. Battaglia-Hsu, and C. Arnold, Endoplasmic reticulum stress in metabolic disorders. Cells, 2018; 7(6):63.
17. Weinberg Sibony, R., et al., Overview of oxidative stress and inflammation in diabetes. Journal of diabetes, 2024;16(10): e70014.
18. Bresilla, D., et al., The sex-specific metabolic signature of C57BL/6NRj mice during aging. Scientific reports, 2022;12(1): 21050.
19. Murt, A., Heart Failure and Renal Dysfunction, in Renal Dysfunction in Cardiovascular Pathologies: Implications for Management. 2026, Springer. p. 153-168.
20. Li, Y., et al., Diabetic vascular diseases: molecular mechanisms and therapeutic strategies. Signal transduction and targeted therapy, 2023; 8(1): 152.
21. Al-Awar, A., et al., Experimental diabetes mellitus in different animal models. Journal of diabetes research, 2016; 2016(1): 9051426.
22. Singh, R., M. Gholipourmalekabadi, and S.H. Shafikhani, Animal models for type 1 and type 2 diabetes: advantages and limitations. Frontiers in endocrinology, 2024; 15: 1359685.
23. Zhang, X., et al., Elevated serum pentosidine is independently associated with the high prevalence

of sarcopenia in Chinese middle-aged and elderly men with type 2 diabetes mellitus. Journal of Diabetes Investigation, 2021; 12(11): 2054-2061.
24. Hsu, C.-N. and Y.-L. Tain, Redox-Driven Precision Medicine for Life-Course Prevention of Cardiovascular–Kidney–Metabolic Syndrome. Antioxidants, 2026; 15(2): 221.
25. Choi, K.J., et al., Development of a pancreatic islet organoid platform for high-throughput drug screening for type 2 diabetes treatments. 2026.
26. Mishra, A.K., et al., Review on diabetes mellitus: an insight into the current scenarios, the challenges of therapy, and application of traditional drugs. Current Traditional Medicine, 2024;10(3): 107-128.
27. Peng, X., et al., Preclinical models for Type 1 Diabetes Mellitus-A practical approach for research. International Journal of Medical Sciences, 2023; 20(12): 1644.
28. Nawaz, M.A., et al., An emerging segment of functional legume-based beverages: A review. Food Reviews International, 2022; 38(5): 1064-1102.
29. Wang, J., et al., Anti-diabetic effects of Inonotus obliquus polysaccharides in streptozotocin-induced type 2 diabetic mice and potential mechanism via PI3K-Akt signal pathway. Biomedicine & Pharmacotherapy, 2017; 95: 1669-1677.
30. Preguiça, I., et al., Diet-induced rodent models of obesity-related metabolic disorders—a guide to a translational perspective. Obesity Reviews, 2020; 21(12): e13081.
31. Wang, Y., et al., Bioinformatics study of the potential therapeutic effects of ginsenoside Rh3 in reversing insulin resistance. Frontiers in Molecular Biosciences, 2024; 11: 1339973.
32. Akter, S., et al., Dietary carbohydrates: Pathogenesis and potential therapeutic targets to obesity-associated metabolic syndrome. Bio Factors, 2022;48(5): 1036-1059.
33. Kapellou, A., et al., Gene–diet interactions in diabetes mellitus: current insights and the potential of personalized nutrition. Genes, 2025; 16(5): 578.
34. Wang, B., P. Charukeshi Chandrasekera, and J. J. Pippin, Leptin-and leptin receptor-deficient rodent models: relevance for human type 2 diabetes. Current diabetes reviews, 2014;10(2): 131-145.
35. Bonetto, S., et al., Management of dyspepsia and gastroparesis in patients with diabetes. A clinical point of view in the year 2021. Journal of clinical medicine, 2021;10(6): 1313.
36. Chandrasekaran, P. and R. Weiskirchen, The role of obesity in type 2 diabetes mellitus—An overview. International journal of molecular sciences, 2024; 25(3): 1882.
37. Wang, A.N., et al., Zucker Diabetic-Sprague Dawley (ZDSD) rat: Type 2 diabetes translational research model. Experimental Physiology, 2022;107(4): 265-282.
38. Abdelhafiz, A.H., D. Emmerton, and A.J. Sinclair, Impact of frailty metabolic phenotypes on the management of older people with type 2 diabetes mellitus. Geriatrics & Gerontology International, 2021;21(8): 614-622.
39. Loewa, A., J.J. Feng, and S. Hedtrich, Human disease models in drug development. Nature reviews bioengineering, 2023;1(8):545-559.

Source of Support: Nil
Conflict of Interest: Nil