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100 YEARS OF INSULIN – DIABETES IN CANADA

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Sonya Norris

Parliamentary Information, Education and Research Services

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100 Years of Insulin – Diabetes in Canada
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EXECUTIVE SUMMARY

The year 2021 marks 100 years since Drs. Banting and Best first isolated insulin at the University of Toronto. The discovery soon changed the lives of people with diabetes worldwide. Several advances have been made since that groundbreaking finding.

Diabetes is a result of the body's inability to properly metabolize sugar. Type 1 diabetes relates to insufficient or no insulin production, while type 2 diabetes relates to the body's inability to respond to insulin and its reduced ability to produce it. There is no cure for diabetes, and if not well-managed, it can have serious short- and long-term health implications.

In Canada, the prevalence of type 2 diabetes has been increasing for many years, partly due to the rising rate of obesity. Since 2000, the diabetes rate has increased by 70%. Indigenous peoples in Canada are at greater risk, with prevalence rates three to five times higher than for non-Indigenous people.

Diabetes is associated with a range of risk factors. Although, the cause of type 1 diabetes is not yet well understood, we do know that food choices, physical activity, age, sex and race or ethnicity are risk factors for developing type 2 diabetes.

Although Canada's federal government implemented a diabetes strategy in 1999, it is unclear whether or to what extent the strategy has been active in recent years. In 2021, Parliament passed legislation to implement a new diabetes strategy.

100 YEARS OF INSULIN – DIABETES IN CANADA

> Formerly, diabetics were half-starved invalids, unable to withstand the stress of ordinary life and easy victims to common infections, very often with disastrous results. The introduction of insulin into therapy has meant a complete revolution of their fate.
>
> Hans Christian Hagedorn, January 1937[1]

1 INTRODUCTION

Diabetes may have been identified as early as 1552 B.C., but it was certainly well documented around 100 A.D.[2] However, it has only been successfully treated for a century following the discovery, isolation and production of insulin. The prevalence – that is, the proportion of affected individuals within the population – of this serious disease has remained steady for most of its history. In recent decades, however, the number of individuals diagnosed with diabetes has increased alarmingly. This paper describes diabetes, summarizes the history of insulin's discovery, explores the impact of the disease in Canada, examines some of the risk factors for developing diabetes and discusses parliamentary and federal government activities with respect to diabetes.

2 WHAT IS DIABETES?

Diabetes is a chronic condition in which a person's body cannot properly metabolize sugar. One symptom of diabetes is frequent urination; this symptom is what characterized the earliest descriptions of the disorder and led it to be described initially as a disorder of the kidneys. This seemingly harmless symptom of diabetes is a result of the body trying to rid its system of excess glucose, or blood sugar. When a person is diabetic, their body's capacity to transport sugar from the blood into cells for energy is impaired. Normally, when food is consumed, sugar is taken up in the blood. When blood sugar levels rise, the pancreas secretes insulin which promotes sugar uptake by cells throughout the body. In a diabetic person, sugar cannot get into most cells, either because the pancreas is no longer producing insulin, or because the body's cells are no longer responding to insulin. The only way left then for the body to rid itself of sugar is to excrete it in the urine. The symptoms of types 1 and 2 are similar and include unusual thirst, frequent urination, weight change, slowly healing wounds, frequent infections, fatigue and blurred vision. However, some people can be diagnosed with type 2 diabetes before noticing any symptoms, if their lifestyle puts them at increased risk of developing the condition, as outlined in section 5.

There are three distinct types of diabetes: type 1, type 2 and gestational, which are described in Table 1. Types 1 and 2 have also been known as juvenile and adult diabetes, as well as insulin-dependent and insulin-independent diabetes, respectively. However, those labels are seldom used anymore, as they are not accurate. Although type 2 diabetes is often diagnosed in adults and does not usually respond to insulin treatment, this is not always the case, and exceptions are becoming more frequent. Similarly, sometimes type 1 diabetes is not diagnosed until adulthood.

Table 1 – Types of Diabetes

	Disease Type	Description
Type 1 diabetes	Autoimmune disorder	Incurable and life-long disease. The immune system attacks and destroys the insulin-producing cells of the pancreas. Consequently, the patient needs to inject insulin or rely on an insulin pump in order to properly use sugar. Almost 10% of individuals with diabetes in Canada have type 1.
Type 2 diabetes	Metabolic disease	Insulin fatigue brought on from chronic overeating or poor diet. In other words, the pancreas has had to chronically over-produce insulin, causing the body's cells to respond to it. As a result, cells throughout the body can no longer respond to insulin, or the pancreas is exhausted and can no longer produce enough insulin. About 90% of individuals with diabetes in Canada have type 2. In many cases it can be reversed or prevented with a healthy lifestyle.
Gestational diabetes	Temporary condition	Develops in the 2nd or 3rd trimester of pregnancy and affects between 3% and 20% of pregnant women. It results from an inability of these pregnant women to produce sufficient insulin to respond to the effects produced by the growing baby and changing hormone levels. It usually reverses after pregnancy, but increases the risk of type 2 diabetes.

Source: Table prepared by the Library of Parliament using information obtained from Public Health Agency of Canada, *Diabetes in Canada: Highlights from the Canadian Chronic Disease Surveillance System*, 2017; and Diabetes Canada, *About Diabetes*.

3 A BRIEF HISTORY OF INSULIN DISCOVERY AND ADVANCEMENTS

> All patients were improved clinically. It is difficult to put in words what is meant by clinical improvement.
>
> Frederick Banting, 1922[3]

The year 2021 marks 100 years since insulin was first isolated from a canine pancreas and successfully used to treat type 1 diabetes. The historic advance, made by the team of Frederick Banting, Charles Best, Bertram Collip and John Macleod at the University of Toronto, saw Drs. Banting and Macleod awarded the 1923 Nobel Prize in Physiology or Medicine.[4] However, the discovery built upon decades of observations and research. Table 2 provides a summary of some work that preceded the first use of insulin to treat diabetes, as well as some of the advances that have taken place since that time.

Table 2 – Timeline of Insulin Discovery and Technological Advances

Year	Milestone	Attribution
1869	A distinct collection of cells is identified within the pancreas, later called the Islets of Langerhans.	Paul Langerhans, University of Berlin
1889	Diabetes can be induced in dogs by removing the pancreas, and it can subsequently be treated temporarily by implanting pancreatic tissue. A pancreatic secretion is responsible for glucose control.	Oskar Minkowski, Joseph von Mering, University of Strasbourg
1901	The Islets of Langerhans are identified as the source of a secretion that controls glucose metabolism.	Eugene Opie, Johns Hopkins University
1914	The Connaught Antitoxin Laboratory is established at the University of Toronto.	John Fitzgerald, Director, Connaught Antitoxin Laboratory
1920	F. Banting designs a research protocol in collaboration with J. Macleod, Chair of Physiology at the University of Toronto.	Frederick Banting and John Macleod
1921	Diabetic dogs are successfully treated with purified pancreatic extract.	Frederick Banting, Charles Best and Bertram Collip
1922	Diabetic children are successfully treated with pancreatic extract, now called insulin. An agreement is reached between the University of Toronto and Eli Lilly & Co. to produce a global supply of insulin at Connaught Antitoxin Laboratory.	Frederick Banting and his team at the University of Toronto
1936	Combining insulin with a protein called protamine prolongs its action; it is later marketed by Novo Nordisk.	Hans Christian Hagedorn, Copenhagen, Denmark
1957	Insulin becomes the first protein to be fully sequenced.	Frederick Sanger, University of Cambridge
1978	Insulin becomes the first human protein to be synthesized using recombinant DNA technology. It is marketed as Humulin® starting in 1982.	Genentech and Eli Lilly & Co.
1985	The first insulin pen delivery system is introduced.	Novo Nordisk
1992	The insulin pump delivery system is introduced.	Medtronic
1996	The first modified human insulin (analog insulin), rapid-acting Humalog, is introduced.	Eli Lilly & Co.
2000s	Research to develop real and artificial pancreas implants to replace insulin treatment is ongoing.	–

Source: Table prepared by the Library of Parliament using information obtained from Diabetes.co.uk, *History of Insulin*, 15 January 2019; The Discovery and Early Development of Insulin, *Interactive Timeline*; Marianna Karamanou et al., "Milestones in the history of diabetes mellitus: The main contributors," *World Journal of Diabetes*, Vol. 7, No. 1, 10 January 2016; and, F.G. Banting et al., "The Effect Produced on Diabetes by Extract of Pancreas," *Transactions of the Association of American Physicians,* Vol. 37, 1922, pp.337–347.

4 BURDEN OF DIABETES IN CANADA

4.1 PREVALENCE AND INCIDENCE OF DIABETES IN CANADA

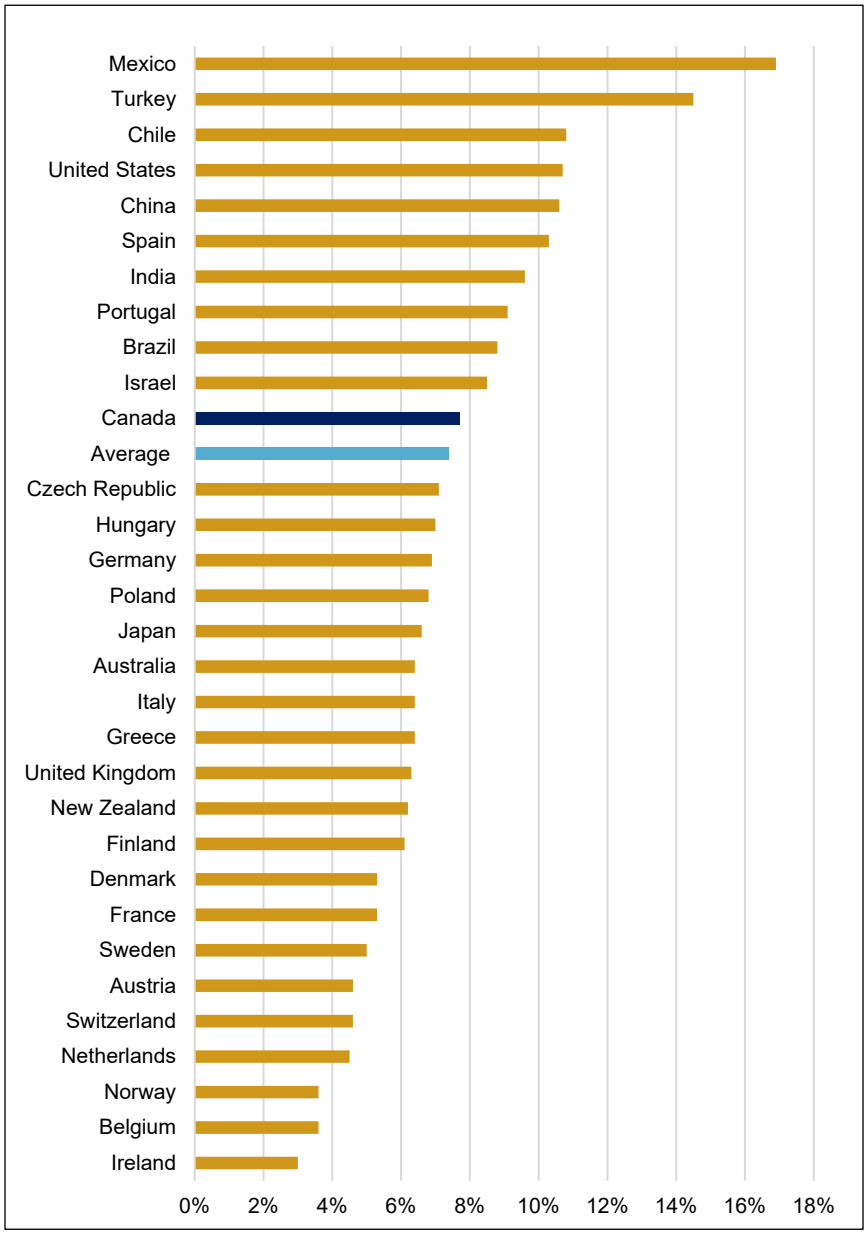
The prevalence of diabetes refers to the proportion of a population living with diabetes at a given point in time. Diabetes Canada indicates that the prevalence of types 1 and 2 diabetes combined in 2020 was 10% of the population, or about 3.8 million Canadians. It estimates that this prevalence could increase to 12% by 2031 and that if people with undiagnosed diabetes and prediabetes are included, those rates could be as high as 29% in 2021 and 33% by 2031.[5] This trend is similar to the global increase in diabetes prevalence.[6]

The prevalence of diabetes among much of the Indigenous population in Canada is higher than for non-Indigenous people. As discussed in section 5, several factors can put individuals at increased risk for diabetes, one of which is their ethnicity. Indigenous populations around the world are at increased risk for type 2 diabetes. The reasons for this are complex but are related to the effects of colonization, including prevalent socio-economic disadvantage. Socio-economic status is predictive of health outcomes as it relates to the social determinants of health. These determinants include income level, job security, education level, housing, food security and social inclusion, among others.[7] As such, the socio-economic disadvantage of the Indigenous population leaves this population vulnerable to developing diabetes.[8]

In 2008, the prevalence of diabetes in Canada overall was 6.8%, whereas the prevalence rates were 17.2% among members of First Nations living on reserve, 10.3% among members of First Nations living off reserve and 7.3% among Métis. Diabetes prevalence among the Inuit population was found to be comparable to the rate among the non-Inuit population.[9] However, diabetes prevalence also varies significantly among the First Nations communities with similar cultural backgrounds. That is, rates are lower in British Columbia and Alberta than they are in Manitoba, Ontario and Quebec.[10] Data from 2015 available from the First Nations Information Governance Centre indicates that diabetes prevalence in First Nations communities remained high at 15.9%, and that only 59.2% of adults from First Nations diagnosed with diabetes had accessed treatment.[11]

Among selected countries of the Organisation for Economic Co-operation and Development, the prevalence of diabetes in Canada ranks near the average, as shown in Figure 1.

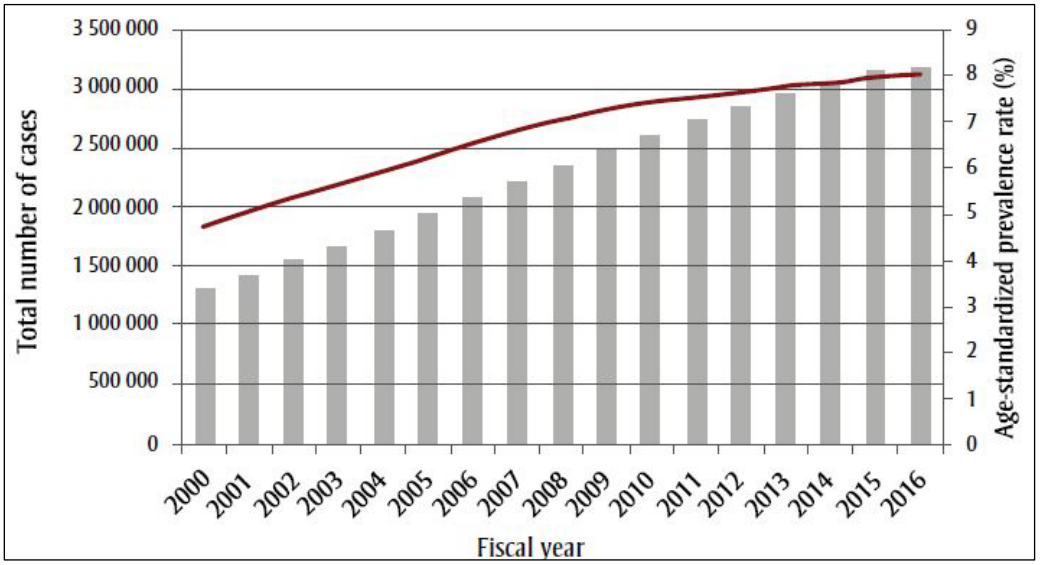
Figure 1 – Age-adjusted Comparative Prevalence of Diabetes Among Adults in Selected Countries, 2019



Source: Figure prepared by the Library of Parliament using data obtained from the International Diabetes Federation, *IDF Diabetes Atlas*, 10th edition, 2021, pp. 104–127.

According to the Government of Canada's *Data Blog*, the prevalence of diabetes rose an average of 3.5% annually between 2000 and 2016, for an overall increase of almost 70%,[12] but it appears to be rising at a faster rate among the Indigenous population.[13] Figure 2 shows the trends in diabetes rates in Canada between 2000 and 2016.

Figure 2 – Number of People Living with Diabetes and Prevalence Rate of Diabetes in Canada, 2000–2016

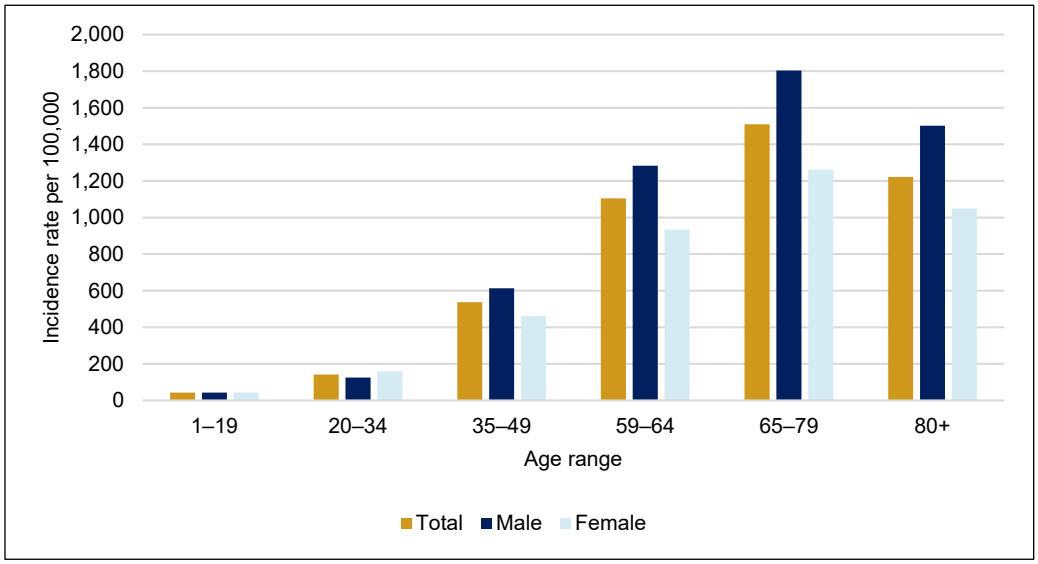


Source: Government of Canada, "Figure 1 – Trends in diabetes rates from 2000/01 to 2016/17, A. Number of total cases, and age-standardized prevalence rate of diabetes," *At-a-glance – Twenty years of diabetes surveillance using the Canadian Chronic Disease Surveillance System*, November 2019.

The increased prevalence can be attributed in part to higher obesity rates, aging of the population and individuals living longer with diabetes. While the greater prevalence of diabetes has been due largely to type 2 diabetes, there are also indications that the rate of type 1 diabetes has also been rising.[14]

The incidence of diabetes – or rate of new diagnoses each year – has remained relatively stable over the same period at about 549 new cases per day since 2000.[15] However, as new cases are more likely to be diagnosed in older Canadians, these cases reflect new type 2 diagnoses.[16] Figure 3 provides the age-adjusted incidence of diabetes in Canada in 2016, by age at diagnosis.

Figure 3 – Age-standardized Incidence Rates of Diabetes in Canada, per 100,000 Population, by Age at Diagnosis, 2017



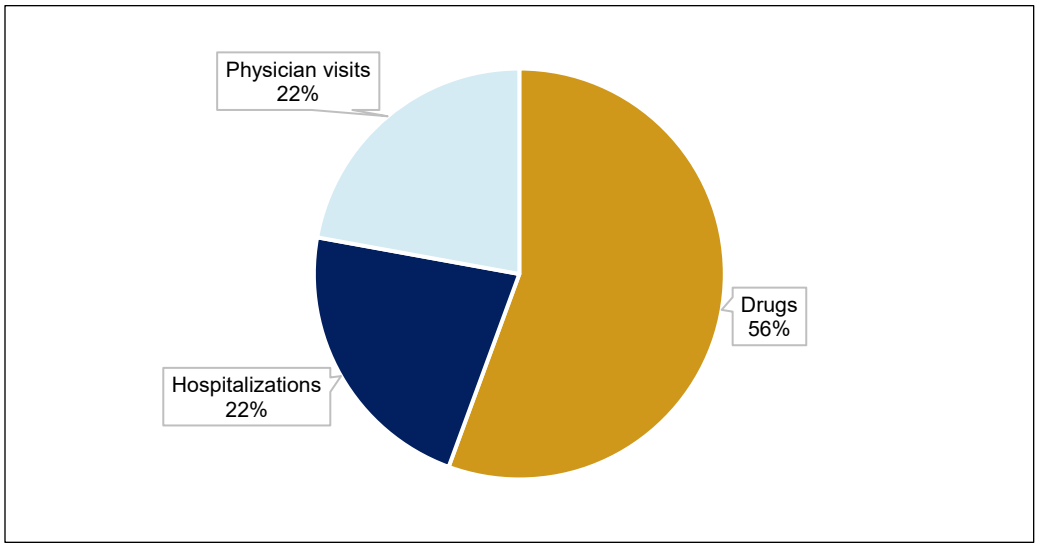
Source: Figure prepared by the Library of Parliament using data obtained from Government of Canada, "Canadian Chronic Disease Surveillance System (CCDSS)," Database, accessed 20 December 2021.

4.2 COST BURDEN OF DIABETES IN CANADA

The burden of diabetes in Canada generates significant costs for affected individuals as well as governments. The total cost burden of diabetes in Canada includes both direct and indirect costs. Direct costs include hospitalizations (in-patient and outpatient), drug therapy, physician and emergency room visits, dialysis, prescriptions and devices.[17] Indirect costs of diabetes include short- and long-term disability and lost productivity due to illness or premature death.[18]

In terms of direct costs, according to a 2017 article, the projected cost of diabetes to the Canadian health care system over 10 years was over $15 billion. This was further broken down to $7.81 billion for the care of men and $7.55 billion for women, reflecting the higher incidence of diabetes among men.[19] Diabetes Canada provided a breakdown of direct costs for 2015, which is provided in Figure 4.

Figure 4 – Distribution of Costs Associated with Diabetes, 2015



Source: Figure prepared by the Library of Parliament using data obtained from Canadian Diabetes Association, *2015 Report on Diabetes* – Driving Change, 2015, p.21.

In 2021, Diabetes Canada estimated that the direct cost of diabetes to the health care system was $3.9 billion for that year, and it projected that this cost would climb to $5 billion by 2031.[20]

Some of the direct costs of diabetes are not covered under provincial health insurance; these costs are likely assumed by individuals, if they do not have private insurance coverage. Diabetes Canada has estimated that people with type 1 diabetes may have a greater annual cost burden than people with type 2 diabetes. People with type 1 diabetes who rely on daily insulin injections could spend up to $2,600 per year, while those receiving insulin pump therapy could spend up to $4,900 per year. Oral medication taken by people with type 2 diabetes could cost up to $1,900.[21] These costs could be even higher for some people with type 2 diabetes who also require insulin therapy.

5 RISK FACTORS FOR DIABETES

There are modifiable and non-modifiable risk factors for diabetes. With respect to non-modifiable factors, both age and sex, as noted above, are risk factors for type 2 diabetes. Genetics and race or ethnicity play a role as well. Modifiable risk factors are the social determinants of health. Poor diet and insufficient physical activity are significant risk factors for developing type 2 diabetes and are directly related to socio-economic status and other social determinants of health.[22] The role of ethnicity or race as a risk factor for diabetes is complex and includes the overlapping contribution of genetics and the social determinants of health.[23] Risk factors are summarized in Table 3.

Table 3 – Risk Factors for Diabetes

Risk Factor	Type 1 Diabetes	Type 2 Diabetes	Explanation
Age	No	Yes	Risk of developing type 2 increases with age.
Sex	No	Yes	Men are at higher risk for type 2 than women.
Genetic variants	Yes	Yes	Type 1 is associated with some gene variants. Not all people with a genetic predisposition develop type 1. Type 2 is associated with genes that predispose a person to obesity.
Environmental factors	Yes	No	Exposure to environmental factors, such as viruses and toxins, may trigger type 1 in those with one or more genetic variants.
Ethnicity or race	Yes	Yes	White people are more at risk for type 1 than Black or Hispanic people. People from First Nations and the Métis, and South Asian, Hispanic and Black people are more likely to develop type 2 than white people.
Diet and exercise	No	Yes	A healthy diet and regular exercise can help to prevent, control and sometimes reverse type 2.

Source: Table prepared by the Library of Parliament using data obtained from the United States, Department of Health and Human Services, National Institute of Diabetes and Digestive and Kidney Diseases, *Symptoms & Causes of Diabetes*; and Diabetes Canada, *Diabetes in Canada: Backgrounder*, January 2021, pp. 3 and 4.

6 HEALTH COMPLICATIONS OF DIABETES

People with diabetes are vulnerable to short- and long-term health complications. The severity of these health complications is largely dependent on how well blood sugar levels are managed from day to day and over a lifetime. Managing blood sugar levels can include monitoring glucose levels, following dietary restrictions or taking insulin, for example. On rare occasions, unregulated blood sugar levels can be fatal. Table 4 describes the short-term health complications of diabetes.

Table 4 – Short-term Health Complications from Diabetes

Condition	Cause	Consequence
Hypoglycemia	Blood sugar level is too low.	Fatigue, weakness, coma.
Diabetic ketoacidosis	Lack of insulin causes the body to break down fat for energy, producing ketones which get released into the blood.	Vomiting, dehydration, coma.
Hyperglycemic hyperosmolar state	Occurs with type 2 diabetes when blood sugar is very high.	Nausea, dehydration, confusion, fever, coma.

Source: Table prepared by the Library of Parliament using information from Diabetes.co.uk, *Short term complications*, 15 January 2019; and International Diabetes Federation, *IDF Diabetes Atlas*, Ninth edition, 2019, pp. 80 and 81.

Blood sugar that is not well controlled over the course of years or decades will cause significant health complications. In fact, diabetes was the sixth or seventh leading cause of death in Canada between 2015 and 2019.[24] Some of the most serious long-term health complications are listed in Table 5.

Table 5 – Long-term Health Complications of Diabetes

Condition	Description	Consequences
Cardiovascular disease (CVD)	CVD includes heart conditions, stroke and peripheral vascular disease. The increased risk for CVD involves multiple mechanisms. In part, elevated blood sugar over the long term makes blood vessels leaky.	Cardiovascular disease is the primary cause of death for people with type 2 diabetes. 30% of strokes and 40% of heart attacks are associated with diabetes.
Renal disease	High blood sugar creates higher pressure within the kidneys, which eventually causes kidney damage. High blood pressure in type 2 can bring about kidney disease.	50% of kidney failure is associated with diabetes.
Peripheral neuropathy and peripheral vascular disease	Nerve damage in the limbs, usually the lower limbs, caused by impaired oxygenation of the nerves because of damage to the blood vessels that supply oxygen to the nerves. Burning and tingling can progress to numbness.	Wounds or ulcers can go undetected, become infected and lead to amputation. This contributes to 70% of non-traumatic lower limb amputations.
Vision problems	These include retinopathy, macular edema, cataracts and glaucoma. Blood flow to the eye is impaired by high blood sugar. This can cause blood vessels to become leaky and provide insufficient blood supply to the retina.	Diabetes is the leading cause of blindness in Canada.

Source: Table prepared by the Library of Parliament using information obtained from International Diabetes Federation, "Chapter 5 – Diabetes Complications and Co-morbidities," *IDF Diabetes Atlas,* Ninth edition, 2019; Diabetes Canada, *Diabetes in Canada: Backgrounder*, January 2021, pp. 1 and 2; and Public Health Agency of Canada, *Diabetes in Canada: Facts and figures from a public health perspective*, 2011.

7 CANADA'S ACTIONS

In 1999, the federal government announced an investment of $115 million over five years to develop the Canadian Diabetes Strategy (CDS), which included $58 million over five years for the Aboriginal Diabetes Initiative.[25] The investment also covered the creation of the National Diabetes Surveillance System the same year; it has since evolved into the Canadian Chronic Disease Surveillance System. In 2005, the CDS was combined into the broader Integrated Strategy on Healthy Living and Chronic Disease (ISHLCD), although funding for the Aboriginal Diabetes Initiative was separate from the ISHLCD.[26]

It is unclear whether or to what extent the CDS is funded currently under the ISHLCD, and there have been calls to implement a diabetes strategy that is separate from the integrated approach. In July 2018, Diabetes Canada called on governments to implement a national diabetes strategy in its report, *Diabetes 360°: A Framework for a Diabetes Strategy for Canada*.[27] The report did not discuss the CDS introduced in 1999, nor did it discuss the existing ISHLCD and the role of the CDS within it. Rather, it outlined the need for a "new" strategy, and with respect to the current approach taken by governments in the fight against diabetes, it stated:

> While extensive effort is being made to address this epidemic, it is not coordinated or comprehensive enough to address the complex issues involved. The present approach that sees the provinces and territories each working on diabetes in their own way has not facilitated economies of scale or rapid knowledge-sharing. The lack of such hallmarks of transformative change has resulted in a patch-work approach to prevention and treatment and great health inequities for people with diabetes across Canada.[28]

Shortly after the release of Diabetes Canada's report, the House of Commons Standing Committee on Health undertook a study on diabetes strategies in Canada and abroad. Its report, issued in April 2019, called on the federal government to partner with provincial/territorial governments and other stakeholders to implement the diabetes strategy as outlined by Diabetes Canada.[29] However, the 42nd Parliament was dissolved before a government response to the report was issued.

On 27 February 2020, Bill C-237, An Act to establish a national framework for diabetes was tabled during the 1st Session of the 43rd Parliament and was reinstated on 23 September 2020 at the start of the 2nd Session. The bill, which passed and received Royal Assent on 29 June 2021, requires the minister of health to develop and implement a national framework designed to support improved access to diabetes prevention and treatment to ensure better health outcomes for Canadians in collaboration with provincial governments and other stakeholders. The framework must include certain measures, such as training requirements for health care professionals and the promotion of research. It also requires the minister to consult with stakeholders for the purpose

of developing the framework, table the framework in Parliament within one year of its coming into force and report on its implementation and impact within five years. There are no specific requirements for the framework to include supports for at-risk population groups, but it does require information-sharing on diabetes prevention.[30] Budget 2021 included funds to implement the new framework as well as other diabetes-related activities starting in 2021–2022. Specifically, it included:

- $25 million over five years for Health Canada for research, surveillance and the prevention of diabetes, and the implementation of the new framework; and
- $10 million over five years for the Public Health Agency of Canada to implement the Diabetes Challenge Prize to encourage the development of new interventions to prevent diabetes.[31]

Budget 2021 also introduced changes that added to the activities recognized as life-sustaining that qualify for the Disability Tax Credit.[32] In terms of extending access to the tax credit to people with diabetes, Budget 2021 introduced an expanded definition of life-sustaining therapy that includes time spent determining dietary intake and physical exertion.[33]

NOTES

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7. World Health Organization, *Social Determinants of Health*.
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13. Regine Halseth, *The Prevalence of Type 2 Diabetes among First Nations and Considerations for Prevention*, National Collaborating Centre for Aboriginal Health, 2019, p. 8.

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19. Anja Bilandzic and Laura Rosella, "The cost of diabetes in Canada over 10 years: Applying attributable health care costs to a diabetes incidence prediction model," *Health Promotion and Chronic Disease Prevention in Canada: Research, Policy and Practice*, Vol. 37, No. 2, February 2017, p. 51.

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21. Ibid.

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24. Statistics Canada, Table 13-10-0394-01: Leading causes of death, total population, by age group," Database, accessed 5 January 2021.

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28. Ibid., p. 7.

29. House of Commons, Standing Committee on Health, *A Diabetes Strategy for Canada*, Twenty-third Report, April 2019.

30. Bill C-237, An Act to establish a national framework for diabetes, 43rd Parliament, 2nd Session.

31. Department of Finance Canada, *A Recovery Plan for Jobs, Growth and Resilience*, Budget 2021, pp. 240–241.

32. Ibid., p. 234.

33. Ibid., p. 590.