Sex and Gender, Socioeconomic Status, and Type 2 Diabetes Mellitus

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Background: Diabetes mellitus imposes challenges on health care systems, economies, and the individuals living with and at risk for this illness. Diabetes is a major chronic disease and affects more and more Canadians each year (Buysschaert & Bergman, 2011; Public Health Agency of Canada (PHAC), 2011). Type 2 diabetes mellitus (T2DM) potentially impacts all people, but it disproportionately affects those who are disadvantaged socially and materially (Brown, 2004). Low income groups have higher diabetes prevalence rates and are at greater risk of developing diabetes than higher income groups (Raphael, 2011). Literature has also indicated that diabetes is related to sex or gender and ethnicity or race (PHAC, 2011; Chiu, Austin, Manuel, & Tu, 2010). In the differences in diabetes risk between men and women, the social aspects of gender, including differences in behaviours and exposures, might play a role (Kautzky-Willer, Harreiter, & Pacini, 2016). Intersectionality describes how the social aspects of gender and other dimensions of risk, particularly low income, might interact (Dhamoon & Hankivsky, 2011; López & Gadsden, 2016). Sex and gender and socioeconomic status (SES) might be significantly associated with T2DM risk and may interact to affect the odds of developing T2DM.

Objective: This study's objective is to improve our understanding of the relationship between SES, sex and gender, and other sociodemographic and behavioural factors, with diabetes risk. Self-reported T2DM status and measures of SES (including household income, economic family household status, working status, education level, and occupational type) and behavioural factors (including type of smoker, alternative tobacco usage, alcohol intake, physical activity level, and fruit/vegetable daily consumption) and perceived stress level were included to investigate whether self-reported T2DM status was significantly associated with income and sex and gender, even after controlling for economic family household status, working status, education level, occupational type, behavioural risk factors and perceived stress level. Analysis aimed to investigate the risk for T2DM among men and women.

Methods: A cross-sectional analysis was completed through multivariable logistic regression analysis with a bootstrapped weighted sample of 77,681 respondents from the Canadian Community Health Survey (CCHS 2015/16). The analytical strategy involved creating two sets of models; one for each of the dependent variables, whether diagnosed with diabetes and the age of diabetes. The first set of models used binary logistic regression to predict the log-odds that an individual was diagnosed with T2DM and included age as a control variable, as well as sex and income, in order to test whether sex and gender and income have independent effects. An interaction of sex and gender and income was included to test whether the effects of income are different for males and females. A second set of models predicted the age at diagnosis of diabetes, among those who had been so diagnosed.

Results: Logistic regression analyses showed a significant association between T2DM and household income. Model 1 showed that females were significantly lower risk compared to males, and there was a clear age gradient, with risks higher among older age ranges. Model 2 presented clear evidence of a gradient in risk according to income, with those in the lowest income decile having nearly 75% higher risk than those in the median deciles and those in the highest income decile having about half the risk. Model 4 showed that females were less likely to report having T2DM than males and that age remained an important predictor of T2DM when other socioeconomic status, geographic, and demographic variables were included in the model. When health behaviours and stress were added (Model 5), along with the variables in the first models, both sex and gender and elements of SES (income, education, work, and family status) were associated with T2DM, although none of the SES variables, other than education, remained significant. Stratified analysis was conducted for Model 6 (males) and Model 7 (females). In the interaction models, the interaction of age and sex/gender was not significant. In the stratified models, the age dummies had a similar effect for males and females and reflected a generally linear relationship with T2DM risk. For Model 8 (men) and Model 9 (women), health behaviours and stress were added to the models for men and women. Overall, these effects of the demographic and socioeconomic variables in these models were similar to those in the stratified models without the behavioural and perceived life stress variables. Results support that sex and gender and SES may interact to affect T2DM risk.

Conclusion: Our results suggest that the two dimensions of social identity-sex/gender and socioeconomic position may interact to structure the risk of T2DM and that there are differences in risk of diabetes for men and women. These results emphasize the importance of studying the observable processes that might be leading to and amplifying observed differences in diabetes risk, which are factors such as age, sex and gender, income, cultural/racial background, education, economic family household, occupation, working status, health behaviours, and stress variables. Our study shows why prevention strategies for T2DM should include approaches that combine healthful behaviours and public policy that identify the key role that SES and sex and gender have on the variations found in the prevalence and incidence of T2DM among the sexes.

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

CIHR	Canadian Institutes of Health Research
CCHS	Canadian Community Health Survey
T1DM	Type 1 Diabetes Mellitus
T2DM	Type 2 Diabetes Mellitus
SES	Socioeconomic Status
SDOH	Social Determinants of Health

1.0 Introduction and Overview

Diabetes mellitus is recognized worldwide for the challenges it imposes on health care systems, economies, and the individuals living with and at risk for this illness. Diabetes, a metabolic disease characterized by high blood sugar, is a major chronic disease and is of growing concern as it continues to affect more and more Canadians (Buysschaert & Bergman, 2011; Public Health Agency of Canada (PHAC), 2011). Specifically, the impact of type 2 diabetes mellitus, (T2DM), which is associated with behavioural and "lifestyle" factors is widespread and has become even more apparent over the last decade (Canadian Diabetes Association (CDA), 2016; PHAC, 2011). In 2016, the prevalence rate of diabetes in Canada was an estimated 9.2% (3.5 million people) and this is predicted to rise to 11.6% (4.9 million people) by 2026 (CDA, 2016). Of these, roughly 90% of diabetes cases are estimated to be T2DM (Raphael, 2011).

T2DM impacts all groups of people in developed countries, but it incommensurately affects adults who are disadvantaged socially and materially (Brown, 2004). Having low income or low socioeconomic status (SES), is directly related to disease prevalence and incidence and is associated inversely with general health (Brown, 2004). In the case of diabetes, low income groups have higher diabetes prevalence rates and a greater risk of developing diabetes than higher income groups (Raphael, 2011). In Canada, diabetes has also been found to be related to sex or gender, with men generally having a higher risk than women, and ethnicity or race, with South Asians and Black Canadians having a higher prevalence than European Canadians (PHAC, 2011; Chiu, Austin, Manuel, & Tu, 2010).

Although there is evidence that endocrine and other biological pathways contribute to the differences in diabetes risk between men and women, the social aspects of gender, including differences in behaviours and exposures, might also play a role (Kautzky-Willer, Harreiter, &

Pacini, 2016). From the perspective of intersectionality, a particularly important question is how the social aspects of gender and other dimensions of risk, particularly low income, might interact (Dhamoon & Hankivsky, 2011; López & Gadsden, 2016).

In this paper, I use the cross-sectional Canadian Community Health Survey (CCHS) 2015 and CCHS 2016 from Statistics Canada, to examine how the relationships between low income and diabetes risk might be different for men and for women. The goal is to improve our understanding of the relationship between socioeconomic status, sex and gender, and other sociodemographic and behavioural factors, in diabetes risk.

We are interested in interpreting the effects of gender, rather than sex for this study. The CCHS 15/16 data does not distinguish between sex and gender. As a result, we will remove the term "sex and gender" from this study and instead refer to gender only for this study. Sex is also an important factor to note in this study, but because of the nature of the data we will focus on sex and gender as gender by using the Canadian Institutes of Health Research (CIHR) framework as a guide for the definitions of sex and gender.

2.0 Literature Review

2.1 Definition of Prediabetes and Diabetes

This section summarizes prediabetes and the types of diabetes, the risk factors of both prediabetes and diabetes, and the complications of diabetes. A detailed description of the disease's progression from the prediabetic state to the chronic state is presented in order to demonstrate the disease's severity and impact on those affected by it.

2.1.1 Types of Diabetes

Diabetes mellitus is a collection of metabolic diseases (Buysschaert & Bergman, 2011). Hyperglycaemia (high blood sugar) is a main characteristic of this disease, which occurs due to the malfunctioning of insulin secretion, insulin action, or a combination of the two (Buysschaert & Bergman, 2011). The point at which glycemic levels indicate an individual has diabetes derives from the observed relationship amongst specific glucose levels and a sharp rise in the prevalence of microvascular complications that have been identified as distinct to hyperglycaemia such as retinopathy and nephropathy (Buysschaert & Bergman, 2011). This chronic disease is challenging to manage and can result in death (Canadian Diabetes Association (CDA), 2017).

There are mainly three types of diabetes mellitus: type 1, type 2, and gestational diabetes. Type 1 diabetes mellitus (T1DM) results when the beta cells of the pancreas, which produce insulin, are damaged. In consequence, type 1 diabetics produce a minimal amount of insulin or no insulin at all, which prohibits sugar from being used as energy for cells. These individuals are required to use insulin injections in order to manage their blood glucose levels. T1DM occurs more frequently in individuals who are younger than 30 years of age. However, T1DM can manifest at any point during an individual’s life (NIDKK, 2017e).

T2DM occurs due to a reduction in insulin production from the pancreas’ beta cells or when the insulin that is produced does not perform as it would normally to allow glucose entry into the cells (National Institute of Diabetes and Digestive and Kidney Diseases (NIDKK), 2017f). As such, with T2DM, the pancreas produces some insulin, but it loses its effects on the cells and tissues in the body (Institute for Quality and Efficiency in Health Care, 2014). Physicians describe this as “insulin resistance” (Institute for Quality and Efficiency in Health Care, 2014). Typically, T2DM manifests in adulthood and occurs because of insulin resistance along with relative insulin deficiency (Raphael, 2011). This results in defective insulin secretion and further insulin resistance (Raphael, 2011). These changes in the body’s use of insulin significantly increase the risk of older adults developing T2DM (PHAC, 2011). T2DM is common in individuals that are overweight and over 40 years of age (middle- or older- aged) (NIDKK, 2017f). T2DM can be regulated by a variety of factors that include diet, weight regulation, and exercising. Medications that reduce glucose levels can be taken orally or by injection (NIDKK, 2017f).

Gestational diabetes is the result of a pregnant woman having a high blood glucose level. Over the course of the pregnancy, the growing foetus develops an increased demand for glucose and the hormone fluctuations that occur during pregnancy impact insulin's effects. These changes during pregnancy cause high blood glucose levels. Pregnant women who have a higher risk of developing gestational diabetes are more than 25 years of age, more than their preferred weight class, have a family history of diabetes, and are of African, Hispanic, Asian, or Native descent (NIDKK, 2017b).

In adults, there are three conditions that must be met in order to be diagnosed with diabetes, as was determined by the National Diabetes Data Group (NDDG) in 1979 after the World Health Organization's (WHO) first Expert Committee Report was released in 1965 and was updated in 1997 (Buysschaert & Bergman, 2011). The conditions are 1) having an explicit increase of plasma glucose level, accompanied by the characteristic symptoms of polyuria, polydipsia, weight loss, and ketonuria, 2) having a fasting plasma glucose (FPG) level equivalent to or more than 126 mg/dL, or 3) having a glucose level equivalent to or more than 200 mg/dL for 2 hours and during another period within 0 to 2 hours (during more than 1 instance) following a 75 gram (g) oral glucose tolerance test (OGTT) (Buysschaert & Bergman, 2011). These conditions have to be met to diagnose a patient with diabetes.

2.1.2 Prediabetes

The concept of “prediabetes” came about in 1979 when the National Diabetes Data Group (NDDG) announced the notion of a metabolic state existing midway between regular glucose homeostasis and diabetes, referred to as glucose intolerance (Buysschaert & Bergman, 2011). Glucose intolerance in people did not correspond with the definition of diabetes, but rather these patients demonstrated glucose levels higher than those deemed as standard (Buysschaert & Bergman, 2011). In 1997, the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus broadened the theory as they began acknowledging individuals who had impaired fasting glucose (IFG) as well as individuals with impaired glucose tolerance (IGT) (Buysschaert & Bergman, 2011).

Individuals with prediabetes do not have observable or clear symptoms (Caballero, Kitabchi, Umpierrez, & Zisman, 2007). Two types of blood tests help to assess the level of glucose in blood and confirm a diagnosis of prediabetes or diabetes (Caballero et al., 2007). The tests for prediabetes are a fasting blood glucose (FBG) test and an oral glucose tolerance test (OGTT) (Caballero et al., 2007). The FBG test involves drawing blood following a fast of eight hours at minimum or overnight (Caballero et al., 2007). The OGTT involves fasting for a minimum of eight hours and drawing blood prior to consuming eight ounces of a sugary mixture and then drawing blood again two hours later (Caballero et al., 2007). A normal fasting blood glucose test values range from 70 to 99 mg/dL and a normal OGTT is below 140 mg/dL (Caballero et al., 2007). Prediabetes is diagnosed when a fasting blood glucose test value ranges from 100 to 125 mg/dL and when the OGTT ranges from 140 to 199 mg/dL (Caballero et al., 2007). Diabetes is diagnosed when the fasting blood glucose test value ranges from 126 mg/dL and above and an OGTT with a reading greater than 200 mg/dL (Caballero et al., 2007).

Currently, IGT and IFG are known as prediabetes and their presence indicate a significant risk factor for the development of diabetes (Buysschaert & Bergman, 2011). Microvascular diseases such as retinopathy, chronic kidney disease, neuropathy, and cardiovascular disease are also linked with prediabetes (Buysschaert & Bergman, 2011). Thus, prediabetes must be considered as a phase in "the natural history of disordered glucose metabolism" (Buysschaert & Bergman, 2011). Prediabetes should not be regarded as a distinguishing "clinical entity" that denotes an intervening state, but should be regarded as a risk factor that predicts the progression and start of diabetes (or an elevated risk for diabetes) and a rise in the number of cardiovascular and potentially microvascular complications (Buysschaert & Bergman, 2011).

2.2 Physical Risk Factors for Type 2 Diabetes Mellitus

Several lines of evidence suggest that the development of T2DM in all individuals is not completely comprehended. Despite this, previous research has identified several physical risk factors that elevate the risk of an individual developing T2DM. These include weight, fat distribution, physical inactivity, family history, race, age, prediabetes, gestational diabetes, and polycystic ovarian syndrome (Mayo Clinic, 2017).

Weight is a risk factor for T2DM because the greater an individual's fatty tissue content, the higher the resistance of an individual's cells are to the effects of insulin. Nevertheless, T2DM can develop in an individual who is not overweight. Additionally, the distribution of fat is a risk factor of T2DM because if the body stores fat mostly in the abdominal region, an individual's risk becomes more than what it would be if fat is stored in other body areas such as the hip and thigh regions (Mayo Clinic, 2017).

Physical inactivity is a risk factor of T2DM since T2DM risk is associated with the activity level of a person. Physical activity supports weight control, utilizes glucose stores, and causes greater sensitivity to the effects of insulin. This means that the lower a person's physical activity level, the higher their risk. Also, family history of T2DM puts an individual at a greater risk of developing the disease (Mayo Clinic, 2017). In the United States of America, it has been found that people of racialized backgrounds including African, Asian, Native American, and Hispanic have higher risk of developing T2DM (NIDKK, 2017f; Mayo Clinic, 2017). Age is also a risk factor of T2DM because as age increases, particularly after age 45, risk continues to rise, possibly as a result of individuals being less physically active as they grow older and old age-related events such as a reduction in muscle mass and an increase in weight (Mayo Clinic, 2017). However, T2DM is considerably rising in youth, teenagers, and young adults (Mayo Clinic, 2017).

As indicated before, prediabetes is a risk factor of T2DM because if this condition is not addressed by lifestyle or medical interventions, it can lead to the development of T2DM (Mayo Clinic, 2017). Also, females who have had gestational diabetes while pregnant are at a higher risk of developing the chronic disease (Mayo Clinic, 2017). A pregnant woman who births an infant that is greater than nine pounds has a higher risk of T2DM (Mayo Clinic, 2017). Lastly, polycystic ovarian syndrome is a risk factor of T2DM because females with this condition have unusual menstruation cycles, abnormally high hair growth, and obesity, which all contribute to increased T2DM risk (Mayo Clinic, 2017).

2.3 Complications of Type 2 Diabetes Mellitus

Complications of diabetes are separated into microvascular and macrovascular (World Health Organization (WHO), 2017). Microvascular complications are a result of injury to blood vessels that are small, whereas macrovascular complications are a result of injury to blood vessels that are big. The microvascular complications of diabetes include kidney damage, known as nephropathy, injury to the eyes, called retinopathy, and nerve damage, referred to as neuropathy. The macrovascular complications of diabetes are comprised of cardiovascular diseases including myocardial infarctions, strokes, and inadequate blood circulation to legs (WHO, 2017).

Diabetic kidney disease or nephropathy is a form of kidney disease that results from having diabetes (National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), 2017d). Diabetes is the primary cause of kidney disease with approximately one in four adults having the disease (Afkarian et al., 2016; NIDKK, 2017d). In individuals with diabetes, high blood sugar can damage blood vessels in the kidney, which causes them to work insufficiently. Damage to the kidneys hinders the filtration of blood, leading to an accumulation of waste in the body, which can result in additional health issues including high blood pressure (NIDKK, 2017d). This damage takes place gradually over the span of several years and can cause death (NIDKK, 2017d; WHO, 2017). In developed nations, diabetic kidney disease is a primary cause of dialysis and kidney transplants (WHO, 2017).

Diabetic eye disease encompasses a number of eye conditions such as diabetic retinopathy, diabetic macular edema, cataracts, and glaucoma, which may present in individuals with diabetes (NIDDK, 2017a). Diabetes is problematic to an individual's eyes when their blood glucose is high and the immediate consequences of diabetes can cause blurred vision due to altered levels of fluid in the eye or swelling of the eye tissues (NIDDK, 2017a). Blurred vision is temporary and ceases once an individual's glucose level nears normal blood glucose (NIDDK, 2017a). However, if blood glucose remains high for a prolonged period of time, damage to the small blood vessels in the back of the eyes can start occurring, potentially during the prediabetic state (NIDDK, 2017a). These blood vessels may seep fluid, which then leads to swelling, resulting in the growth of new and feeble blood vessels that may bleed in the middle of the eyes or produce very damaging high pressure in the eyes (NIDDK, 2017a). Scarring occurs as a result of these changes, leading to vision loss or blindness (NIDKK, 2017a).

Diabetic neuropathies are a group of nerve conditions resulting because of diabetes (National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), 2013). Nerve damage can extend through an individual's body over time and can affect all organs in the body (NIDDK, 2013). Neuropathies affect approximately 60 to 70 percent of individuals with diabetes (NIDDK, 2013). Nerve problems can appear whenever, with the risk of further nerve damage occurring with older age and the longer the disease continues (NIDDK, 2013). Individuals with diabetes can develop nerve damage from metabolic factors including hyperglycaemia, having diabetes for a long time, irregular levels of blood fat, and potentially small levels of insulin; neurovascular factors that can cause blood vessels damage and affect the flow of oxygen and nutrients to nerves; autoimmune factors that lead to nerve inflammation; mechanical damage to nerves including carpal tunnel syndrome; hereditary traits that make it more likely that neuropathy will occur; and lifestyle factors including consuming alcohol and smoking (NIDDK, 2013). Damage to nerve may result in sensory loss, damages to extremities, and erectile dysfunction in males (WHO, 2017).

Individuals with diabetes have a greater likelihood of developing cardiovascular disease (National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), 2017c). Consequently, these individuals are at higher risk for heart attacks and strokes and they also have an increased risk of developing conditions or risk factors that contribute to a higher risk of heart attacks and strokes, which include high blood pressure (hypertension) and high cholesterol. This is due to diabetes increasing cardiovascular disease risk in individuals as time progresses with the disease because having a high blood sugar leads to blood vessel damage as well as nerve damage in the nerves responsible for regulating a person's heart and blood vessels. As such, having diabetes for an extended period of time increases the likelihood that an individual will develop cardiovascular disease. Individuals living with diabetes are more inclined to develop heart disease at an age less than the age of individuals who do not have diabetes. For diabetic adults, cardiovascular disease is the leading cause of death (NIDKK, 2017c). Therefore, the macrovascular complications of diabetes are significantly problematic to the health and longevity of an individual.

2.4 Diabetes Prevalence in Canada

The national prevalence of diabetes and prediabetes demonstrates the significance of the disease in Canada. Canadian Community Health Survey (CCHS) data from 2015 indicate that 6.9% of Canadians aged 12 years old and above had been diagnosed with diabetes, accounting for roughly 2.1 million individuals (Statistics Canada, 2017b). There was an important gender difference in prevalence; 5.9% of women indicated that they had diabetes compared to 7.8% of men in 2015 (Statistics Canada, 2017b). The prevalence of Canadians with diagnosed diabetes also differed amongst the provinces (Statistics Canada, 2017b). The proportion indicating that they had diagnosed diabetes was less than Canada's average of 6.9% in Alberta (4.7%) but higher in Newfoundland and Labrador (10.5%), Nova Scotia (10.1%), and New Brunswick (8.8%) (Statistics Canada, 2017b). In the remaining provinces, the proportion of residents indicating having received a diagnosis of diabetes was close to Canada's average of 6.9% (Statistics Canada, 2017b).

These prevalence rates put Canada as among the countries with the greatest proportion of diabetes (Chief Public Health Officer, 2016). The prevalence of diabetes has made it such that diabetes has made the top ten of the leading causes of death in high income nations and is the seventh leading cause of mortality in Canada (Brown, Nevitte, Szeto, & Nandi, 2015).

The majority (90 to 95 percent) of diabetes cases in Canada are Type 2 diabetes mellitus (T2DM) (Public Health Agency of Canada (PHAC), 2015), and more than 60,000 new cases of T2DM occur annually (Government of Canada, 2015). Demographic aging contributes to this, as risk becomes higher as individuals grow older (PHAC, 2011). However, the age at onset of T2DM appears to be declining and, although T2DM was traditionally considered as a disorder that affected adults, in the past 20 years before 2011, the prevalence of T2DM among children and adolescents has increased (PHAC, 2011; Raphael, 2011). Although the diagnosis of diabetes is still seen more often in adults of older ages, Canadians in the working ages of 25 to 64 years old accounted for over 50% of those diagnosed with diabetes in 2008/09 (PHAC, 2011).

There is important evidence that the risk of T2DM is strongly structured by socio-demographic factors (PHAC, 2011). Having low socioeconomic status, being of specific ethnic backgrounds, and residing in rural regions are linked to higher rates of T2DM and related mortality, as well as higher prevalence of behavioural risk factors for the disease (PHAC, 2011).

2.5 Implications of Type 2 Diabetes Mellitus Prevalence

T2DM is a chronic disease, meaning that as this disease continues to progress, remains undiagnosed, or is left untreated, the damage occurring to the body as a result of the effects of the disease accumulate and can culminate in several complications varying in severity and eventually, can lead to death (PHAC, 2011). T2DM is an incapacitating disease because of the various complications that present in the affected individual over time (PHAC, 2011). The effects of T2DM cause those affected to experience substantially diminished quality of life, reduced ability to work, and a higher mortality risk (PHAC, 2011). These consequences cause the cost of diabetes across Canada to increase and generate a greater need for health care services and supplies (PHAC, 2011).

In the last several years, the rates of complications of diabetes have fallen and become constant (PHAC, 2011). However, the higher rates of Canadians with diabetes in recent years have resulted in a persistent increase in the numbers of people experiencing complications of this chronic disease (PHAC, 2011). As described above (Section 2.3), short-term complications of diabetes resulting from hyperglycaemia include higher risk of infections, prolonged healing of lesions, and diabetic ketoacidosis. Long-term complications of diabetes caused by hyperglycaemia, hypertension, and dyslipidemia include macrovascular and microvascular complications. Despite these possible complications, there are ways in which diabetics can lead a healthy life as well as defer or stop any complications from occurring. Diabetes can be managed by monitoring the level of glucose and lipids in an individual's blood and regulating the individual's blood pressure, through the modification of personal habits and behaviour and by using treatments such as medicines (PHAC, 2011).

Managing both type 1 and type 2 diabetes involves reducing and trying to eradicate the disease's symptoms and risks that occur in the short-term due to increased or decreased glycemic levels. Managing diabetes also involves preventing or slowing down the advancement of any long-term complications of the disease, which can be achieved by performing preliminary detection tests and administering treatments (PHAC, 2011). Management of diabetes is focused on glycemic control, which is "the cornerstone" of managing this disease, due to the prominent link between hyperglycaemia and high rates of diabetic complications (PHAC, 2011). In order to best prevent and reduce complications of the disease, the affected person exercises self-management and receives care from healthcare specialists such as physicians, nurses, pharmacists, dieticians, and health mentors specializing in diabetes (PHAC, 2011). Medicine may be used to regulate glycemic levels and is often necessary because of the progressive nature of the disease. For T2DM, oral medicine is typically given during the less advanced stages of the disease. Insulin is administered by injection and is needed for all people with T1DM, but it can be given to some people with T2DM to help them manage their glycemic levels if lifestyle modifications or oral medicines are unsuccessful or if complications emerge (PHAC, 2011).

2.5.1 The Health Burden of Diabetes in Canada

The burden of diabetes on the Canadian healthcare system is significant. Much is a result of the need for health care services to diagnose, monitor, and provide care by health professionals and treatment to the affected Canadians to help them manage their chronic disease and any of its associated complications that may develop (PHAC, 2011). For instance, the Canadian Chronic Disease Surveillance System (CCDSS) reported that from 2008 to 2009, individuals 20 to 49 years old with diabetes visited a family doctor twice as often on average, and went to a specialized health professional two or three more times than people without diabetes (PHAC, 2011). Specialist visits made by children and adolescents (one to 19 years old) with diabetes were very common. This group had quadruple the average number of visits as young people without diabetes in 2008/2009 (PHAC, 2011). Consequently, the burden of diabetes on the healthcare system due to extensive healthcare utilization is considerable.

The frequency of healthcare service utilization by individuals who have diabetes is evident when looking at sex and age. Rate ratios of the number of visits to a family doctor by persons one year old and above and diabetes status in Canada provide further illustration of the burden placed on the healthcare system in Canada. These rate ratios indicated a difference between sexes for health service utilization, especially, for women in the age range at which pregnancy can occur. This was explained by the fact that women without diabetes visit family doctors much more than men do (PHAC, 2011). In all age groups, individuals with diabetes had more hospital stays than individuals who did not have diabetes (PHAC, 2011). Data from 2006 to 2007 showed that the average time of hospital stays for individuals with diabetes who were between 20 to 54 years old was four to six times the amount of days spent by those who did not have diabetes (PHAC, 2011). Also, for individuals with diabetes above 65 years of age, the average time spent in the hospital was 1.5 to 2.5 times higher when compared to individuals who did not have diabetes in 2006/2007 (PHAC, 2011). Similarly, CCDSS reported that from 2008 to 2009, individuals with diabetes who were hospitalized once, at minimum, within the year was nearly triple times those who did not have diabetes (PHAC, 2011). Children and adolescents who were affected by diabetes had nearly seven times the number of hospital stays than those children and adolescents without the disease (PHAC, 2011). These findings illustrate how frequently healthcare services are used to help people affected by diabetes manage their disease. As a result, the burden of diabetes on the Canadian healthcare system is tremendous and needs to be considerably reduced.

Effective prevention and management of the disease is key to reducing its burden. This includes reducing the economic burden of diabetes on the Canadian healthcare system due to its high cost (Bilandzic & Rosella, 2017). The total cost of diabetes includes indirect costs that are a result of diabetes and its complications that cause premature death, morbidity, and disability and direct costs due to diabetes and its complications that lead to hospital stays, emergency room visits, visits to doctors, medication use, and out-of-pocket fees for materials and treatments (PHAC, 2011). As such, determining a comprehensive list of all the contributing costs of diabetes is difficult to accomplish. Studies thus far have employed several methods to produce estimates that have differed. This is because different methodologies and samples have usually been restricted to particular groups of populations (PHAC, 2011). The provincial and territories' medical billing systems have helped to estimate the direct costs of services provided by health care, but they are unable to completely reproduce all the services utilized and offered to individuals with diabetes such as counselling by nutritionists and non-medical health advisors (PHAC, 2011). The estimated indirect costs due to diabetes are hard to determine because stipulating per person costs that cause reduced productivity and early mortality is broadly ranged (PHAC, 2011).

The Economic Burden of Illness in Canada (EBIC) study presents estimates of the economic burden of diabetes (PHAC, 2014). EBIC 2000 CAD estimated all costs attributed to diabetes at $2.5 billion in year 2000 CAD, not including the costs resulting from diabetic complications (PHAC, 2011). The national estimate of total direct costs of health due to diabetes was $769.4 million in 2000, exclusively for primary diabetes management (PHAC, 2011). Bearing in mind the direct costs of caring for more common medical illnesses and diabetic complications, direct costs to health care could be estimated to be around 4.5 times higher than diabetes alone (PHAC, 2011). These were estimated by EBIC 2000 to be $1.7 billion in year 2000 CAD (PHAC, 2011). Breaking down the indirect costs showed that greater than $1.0 billion was due to premature death and $671.7 million was a result of short- and long-term disability caused by diabetes directly (PHAC, 2011). This might be an underestimation because the indirect costs of diabetes complications, the major causes of disability and premature death for the disease, were not taken into consideration (PHAC, 2011).

The estimated cost of care provided by hospitals and doctors and the medications used to treat diabetes in 2008 was $2.18 billion (PHAC, 2014). Recently, the Canadian Diabetes

Association (CDA) indicates that the cost of diabetes to the health care system was $3.4 billion in 2016 and this is anticipated to rise to $5 billion by 2026 (CDA, 2016). The estimated cost attributed to each incident case of the disease during the first year of diagnosis in Ontario was about $2930, and in the years following, the estimated cost was $1240 (Goeree et al., 2009). Bilandzic and Rosella (2017) accounted for Goeree and his colleagues' research when they continued their research to estimate that the mean cost attributable in the eight years of check-ups after diagnosis was $9,731 for women and $10,315 for men (Bilandzic & Rosella, 2017). Therefore, the enormous economic burden on the healthcare system is evident as noted by the direct and indirect cost estimations.

2.6 Low Income or Low Socioeconomic Status and T2DM Risk

As described above, people with low socioeconomic status (SES) have been found to be at higher risk for T2DM (Dinca-Panaitescu et al., 2012; Rabi et al., 2006) and to have higher mortality risk due to diabetes (Rabi et al., 2006). SES and its several elements, including, income (as a main element), level of education, and occupation, are recognized as social determinants of health (Agardh, Alleck, Hallqvist, Moradi, & Sidorchuk, 2011; Rabi et al., 2006).

The distribution of cases of diabetes in the country shows an alarmingly high proportion of people in low-income groups (Raphael, 2011). For example, diabetes can be as much as two times as common in lower income groups than in higher income groups (Rabi et al., 2006). The Canadian Institute for Health Information found that Canadians aged 18 years and above, between 2003 and 2013, in the poorest income quintile had the highest likelihood of reporting that they developed diabetes when compared to the other four higher income quintiles (Canadian Institute for Health Information (CIHI), 2016). The Canadian Community Health Survey (CCHS) indicates that the lowest income population's T2DM prevalence rate is approximately four times that of the highest income quintile's rate (Dinca-Panaitescu et al., 2011). The prevalence rates for men in low-income communities were 40% more and 50% more for lower-middle-income communities than the rate of high-income communities (Raphael, 2011). Cross-Canadian data show that the prevalence of diabetes in individuals between 45 to 64 years old with household incomes of $10,000 to $29,999 is double, or 6%, the prevalence of individuals with household incomes of $60,000 and above, or 3% (Raphael, 2011). Therefore, income level as a SDOH is associated to the prevalence of people living with diabetes (Rabi et al., 2006).

Higher hospitalization rates due to acute diabetic complications have been found in individuals with diabetes who are of low income (Rabi et al., 2006). Booth and Hux (2003) have shown that the poorest Canadians with diabetes had 43% more hospital admissions than the richest individuals with diabetes mellitus, despite having a universal healthcare system in Canada.

The reasons for the higher risk among low SES populations are complex. To some degree, the higher incidence of diabetes in poorer populations can be attributed to the risk factors they face, which include aspects of the physical and social environments, sedentary lifestyles, and obesity (Agardh et al., 2011; Hsu et al., 2012). In addition to those risks are the conditions that cause the poorest individuals to be the most vulnerable to stressors linked to health, which include financial burden and the experience of prejudice (Pearlin, Schieman, Fazio, & Meersman, 2005). The risk of developing diabetes may also be related to complicated processes that concern poor individuals' access to resources and services provided by healthcare and to information (Agardh, et al., 2011).

The higher risk of diabetes among low SES populations has been found in other high-income countries as well as Canada. This relationship is contrary to the case in middle- and low-income nations, where those in higher social strata have higher risk (Agardh, et al., 2011). This may be attributable to the reversed relationships between SES and lifestyle and obesity risks which are higher in low SES populations in high income countries, but are more prevalent in high SES populations in rapidly developing ones (Agardh, et al., 2011).

2.7 Potential Mediating Factors: Food Insecurity, Stress and Food Literacy

There are several potentially mediating factors that might help to explain the relationship between having low income or low socioeconomic status and the risk of diabetes. Food insecurity is a social determinant of health that is strongly associated with T2DM (Fitzgerald, Hromi-Fiedler, Segura-Pérez, & Pérez-Escamilla, 2011). Households are described as food insecure when there is an inadequate opportunity to obtain nutritional food that is satisfactory and innocuous in a publicly accepted manner (Fitzgerald et al., 2011). Food insecurity has been linked to low SES, poor diet diets, being obese, not exercising, having increased symptoms of depression, and T2DM (Fitzgerald et al., 2011; Seligman, Bindman, Vittinghoff, Kanaya, & Kushel, 2007). Similarly, a Canadian study on household food insecurity and diabetes found that diabetes is associated with food insecurity prevalence and higher probability of engaging in unhealthy behaviours, experiencing psychological distress, and being of poorer physical health (Gucciardi, Vogt, DeMelo, & Stewart, 2009).

Food insecure households may replace the foods that are desired with less expensive food substitutes that are not usually nutritious, but rather high in calories (Drewnowski & Darmon, 2005). Food insecurity has been found to be associated with diets that are low in fruits and vegetables, and that have a higher caloric intake percentage, due to the intake of fat and refined carbohydrates, and such food consumption patterns are linked with the development of diabetes (Kendall, Olson & Frongillo, 1996; Lee & Frongillo, 2001; Tarasuk, 2001). Food insecurity might also result in anxiety about the lack of food, modification of food spending, and consuming less food or skipping meals (Seligman et al., 2007). Food insecure individuals might also consume more than necessary during periods of food adequacy, leading to cyclic sequences of binging and fasting (Seligman et al., 2007). Insulin resistance is associated with such food consumption patterns (Duska, Andel, Kubena & Macdonald, 2005; Mansell & Macdonald, 1990; Newman & Brodows, 1983).

Another important factor to consider that affects the development of T2DM in both males and females is stress. Perceived stress was found to be a profound T2DM risk factor in a longitudinal study (Harris et al., 2017). Likewise, psychosocial stress experienced in adult years has been linked to an increased risk of T2DM, which may be facilitated by behavioural and physiological elements that require additional examination of the principal causal factors (Crump, Sundquist, Winkleby, & Sundquist, 2016). A cohort study also found that low stress resilience during the late years of adolescence might significantly moderate the causal pathways of T2DM in the future (Crump et al., 2016). Psychosocial stress might exacerbate lifestyle behaviours that are not healthful and that are recognized risk factors for the disease (Crump et al., 2016). These risk factors include sedentary behaviour, poor diet patterns, smoking, and alcohol abuse (Crump et al., 2016). Chronic stress triggers the hypothalamic-pituitary-adrenal (HPA) axis, leading to greater cortisol release that can promote obesity in the abdomen and also cytokine-mediated immune reactions that possibly play a role in mediating insulin resistance (Crump et al., 2016). This signifies that the risk of T2DM is linked to an individual's resilience to stress.

Health literacy is defined as a range of proficiencies that an individual must have in order to operate in the health care environment (Berkman, Terry, & McCormack, 2010). Individuals affected by diabetes who have insufficient health literacy have demonstrated poor health outcomes and adverse consequences to healthcare (Powell, Hill, & Clancy, 2007; Sarkar et al., 2010; Schillinger et al., 2002; Schillinger et al., 2004). T2DM is also associated with health behaviours, such as level of physical activity and dietary nutrition, and merits the exploration of the risk of T2DM due to lifestyle and health related behaviours because ethnic and racial minority youth in the United States of America (U.S.A.) have demonstrated less physical activity and poorer diets that included less fruits and vegetables, but higher sugar consumption than white youth (Holl, Jaser, Womack, Jefferson, & Grey, 2010). Food insecurity, stress, health literacy, and health behaviours are therefore, critical to investigate, as they are associated with T2DM.

2.9 Other dimensions of risk for T2DM

In addition to low income Canadians, there are other groups of Canadians at higher risk to T2DM. These include Indigenous Canadians and members of some other ethnic groups. As well, there are reasons to think that some immigrants to Canada might be at higher risk.

2.9.1 Indigenous Peoples

Indigenous Canadians are at an increased risk of both diabetes and having low incomes, compared to other Canadians (Raphael, 2011). The Indigenous peoples in Canada are made up of the First Nations, Inuit, and Métis who reside in a spectrum of communities, varying from big metropolises to small communities and remote areas (Harris, Bhattacharyya, Dyck, Hayward, & Toth, 2013). There is a greater rate of poor health outcomes among Indigenous peoples that is linked to several determinants, such as nutrition, fitness level, genetic vulnerability, psychosocial causes, historical and political events, Indigenous culture, spiritual acts, low income, low education level, limited access to healthcare, greater unemployment rates, inadequate living conditions, minimal social support, stigma, and being adversely stereotyped (Harris et al., 2013).

The national age-adjusted prevalence of diabetes revealed that rates are three to five times greater on First Nations reserves than in the country's general populace. In 2008/2010, 16% of First Nations adults who were on-reserve indicated they had been given a diagnosis of diabetes, with 81% having T2DM (First Nations Information Governance Centre, 2012) and prevalence rates are as high as 26% in individual First Nations (Harris et al., 2013). Off-reserve First Nations also had a higher likelihood of indicating that they had diabetes when compared to other groups in 2007/2010 (Gionet & Roshanafshar, 2013).

Among First Nations, women have a higher rate than men (Harris et al., 2013). Among First Nations women, the highest prevalence rates were during reproductive years, at more than 20%, compared with 16% among First Nations males (Harris et al., 2013). However, Métis women and men were found to have comparable diabetes prevalence rates (Harris et al., 2013).

2.9.2 Race and Ethnicity

Racialized and ethnic minority populations vary in their risk of developing diabetes (Creatore et al., 2010). In Canada, ethnic groups identified as having higher risk of developing diabetes are East Asians, South Asians, African Canadians, and Hispanics (Kelly & Booth, 2004). Non-European ethnic populations have been shown to have a greater prevalence of diabetes (Creatore et al., 2010). Additional studies conducted in Canada and in other countries thus far have similarly indicated that persons of South Asian and African descent are at a greater risk of developing diabetes than Caucasians (Tenkorang, 2016).

2.9.3 Diabetes among Immigrants

More than 250,000 immigrants come to Canada each year, with the greatest number of individuals coming from Africa, Asia, and the Middle East (Creatore et al., 2010). Recent immigrants coming to Canada have a greater risk of T2DM due to a variety of variables such as low income, genetic profile, nutritional transition, stress due to acculturation, experiencing social isolation, minimal physical activity, and facing cultural differences and language barriers when using healthcare services (Ilene, Shakya, Jembere, Gucciardi, & Vissandjée, 2017). Literature suggests that the prevalence of T2DM is greater in non-European individuals and that non-European ethnicities make up a large number of immigrants entering Canada (Creatore et al., 2010). However, the epidemiology of diabetes in immigrants entering Western nations, like Canada, is not well understood. The prevalence of T2DM is typically greater in developed nations, but has started to swiftly rise in developing nations (Creatore et al., 2010).

Creatore et al. (2010) conducted a study with "a unique population-based data set in a setting with high rates of immigrants" to illustrate the disease's epidemiology of the disease within "a heterogeneous immigrant population" by using administrative health and the immigrants' records. The study acknowledged that Ontario's population has a vast range of ethnic populations and found that the relative rates of the disease in South Asian, Latin American, Caribbean, North African, and Middle Eastern immigrants were high (Creatore et al., 2010). Also, immigrants from South Asia were found to have, at minimum, three times the risk of diabetes than that of Western European and North American immigrants, while Latin American, Caribbean, and sub-Saharan African immigrants had about twice the risk, even with sex, age, time since arrival, level of income, and other relevant immigrant factors being controlled (Creatore et al., 2010). Overall, new immigrants, especially females and those of

South Asian, Caribbean, and African ethnicity were found to have an increased likelihood of developing diabetes than individuals who lived in Ontario as residents (Creatore et al., 2010).

Socioeconomic status (SES) is complexly associated with race in Canada, partly because of immigration (Tenkorang, 2016). Visible minority immigrants might have had relatively high SES in their countries of origin, but might have lower status after landing in Canada (Tenkorang, 2016). Various studies regarding visible minorities revealed that immigrants from Africa and South Asia, especially, have lower incomes in Canada in spite of their educational and occupational qualifications (Tenkorang, 2016). Accordingly, their risk of being adversely affected by low income may be the reason their health outcomes are poorer and their burden of disease is greater for diseases such as diabetes (Tenkorang, 2016).

2.10 Sex and Gender Definitions

Sex and gender are a main focus of this thesis. In order to account for their significance in this study, these terms will be defined. Sex and gender are not interchangeable terms (Canadian Institutes of Health Research, 2020). Sex is the biological characteristics in humans and animals and is related to physical and physiological qualities such as “chromosomes, gene expression, hormone levels and function, and reproductive/sexual anatomy” (Canadian Institutes of Health Research, 2020). The make up and expression of biological traits of sex are diverse despite the classifications of male and female (Canadian Institutes of Health Research, 2020). Gender pertains to girls’, women’s, boys’, men’s, and non-binary people’s “socially constructed roles, behaviours, and expressions and identities” (Canadian Institutes of Health Research, 2020). Gender is not binary and or fixed, but rather it can change with time and “exists along a continuum” (Canadian Institutes of Health Research, 2020). Gender can impact how individuals behave or connect with each other, view themselves and others, and affect power dynamics and "societal resources" (Canadian Institutes of Health Research, 2020).

2.11 Sex/Gender Differences in T2DM

Males and females are not equally at risk to diabetes. In 2017, 1,279,500 males (8.4%) and 986,100 females (6.3%) 12 years of age and above had diabetes (Statistics Canada, 2018). The reasons for these differences are complex. They might be due to biological factors, such as endocrine functions. There is evidence that sex hormones play a role in increasing the risk in women and decreasing risk in men (Ding, Song, Malik, & Liu, 2006; Kautzky-Willer et al., 2016), and that oestrogen receptors might make it more likely that obesity leads to metabolic syndrome among women than among men (Mauvais-Jarvis, 2015; Meyer, Clegg, Prossnitz, & Barton, 2011).

However, there are also reasons to expect that social aspects of gender might be important. Men and women may differ in the use of preventive care, their health behaviours, and their access to healthcare and treatment, which in turn affect diagnoses and health outcomes (Payne, 2009; Kautzy-Willer et al., 2016). For example, there is evidence that women tend to be more inactive and to consume more sugar, on average, than men (Kautzky-Willer et al., 2016). Smoking is also a risk factor for diabetes in both men and women (Kautzky-Willer et al., 2016), and prevalence of tobacco smoking is higher among Canadian men than women (Reid et al., 2017).

Men and women also differ in their life course exposures to risk of poverty and low SES. Women in Canada have lower average personal income than men, although the gap has been decreasing over the past several decades (Fox & Moyser, 2018). Women are more likely to spend some time in poverty, to be lone parents, and to rely on social assistance (Fox & Moyser, 2018). As described above, low SES might increase diabetes risk through material pathways, such as poor access to healthful food or recreation opportunities, as well as through psychosocial pathways and stress response (Kelly & Ismail, 2015).

These gendered differences in behaviour and exposure are almost certainly implicated in the observed differences in risk for men and women, but in complex ways. Some of these differences, such as higher smoking rates, might help to explain some of the higher T2DM risk among men. On the other hand, factors such as diet and exposure to poverty would tend to increase women's risk, confounding the observed male/female difference in unadjusted rates.

To make the situation more complicated, it appears that gender can interact with biological, behavioural, and social determinants of health to produce different patterns of risk for men and for women. This has been found particularly in the case of socioeconomic status. Using the 1996–97 National Population Health Survey, Tang, Chen, and Krewski (2003) found that, although low education and income were related to T2DM risk among men and women, after adjustment for age, region, obesity and physical inactivity, the relationship between these measures of SES and T2DM were no longer significant among men, although they remained so for women. Dasgupta, Khan, and Ross (2010), using the 2000–02 Canadian Community Health Survey, also found differences between men and women in the way that socioeconomic status structured T2DM risk. After adjustment for age, geography, ethnicity, BMI, physical activity, smoking, some chronic conditions, depression and physician visits, T2DM risk among women increased monotonically with lower education and income levels. Among men, adjusted risk was only significantly higher for those in the lowest categories of education and income (Dasgupta, Khan, & Ross, 2010).

De Melo, de Sa, and Gucciardi (2013) using the 2007–08 CCHS, examined the characteristics of men and women with and without diabetes, and found that women with diabetes were more likely to be in lower income quintiles, and to have lower educational attainment than were men with diabetes. Using 2011–12 CCHS data and the previously validated Diabetes Population Risk Tool algorithms, Rivera, Lebenbaum, and Rosella (2015) generated probabilities of developing physician-diagnosed diabetes within 10 years, for the CCHS sample. These were then regressed on a number of individual, household and area-level SES indicators. Low household education and income had a stronger effect on women's likelihood of being in the high-risk category than men's, and food insecurity was only a significant predictor of high risk among women, in models adjusted for age, ethnicity, immigrant status, self-perceived health, smoking, physical activity and life satisfaction (Rivera et al., 2015).

3.0 Study Rationale and Analytic Frameworks

The existing body of knowledge suggests that low SES, measured by income and education, is a predominant risk factor for the development of T2DM in Canada. However, there is also evidence that the relationship between low SES and diabetes risk is different for men and for women, and that it is a more reliable predictor of diabetes among women. Although these relationships have been fairly well documented with Canadian data, there has been little research attention given to understanding the reasons why the relationships between low income and diabetes risk might be different for men and for women. This research will examine this question, guided by two analytic frameworks; the social determinants of health (SDOH) and intersectionality.

3.1 Social Determinants of Health Frameworks and T2DM Risk

There are several frameworks for the social determinants of health. The frameworks have been used to organize these determinants and to describe their relationships to each other, and to health outcomes, such as type 2 diabetes (T2DM). The simplest frameworks are the socioecological models which place individual factors at the most proximate level, societal factors in the centre, and the general socioeconomic, cultural and environmental factors at the most distal level. This model, in particular, is the Dahlgren and Whitehead (1991) model of social determinants of health that distinguishes the various social determinants that can be used to possibly theorize policies and interventions.

Numerous SDOH frameworks have been constructed to demonstrate that individual-level factors, including biological and physiological characteristics and health-related behaviours, that manifest are influenced by social and environmental context (Institute of Medicine (US) Committee on Women's Health Research (IMCWHR), 2010). The differences between specific frameworks concern the order of health determinants and the structuring of frameworks for the determinants (IMCWHR, 2010). Consequently, some SDOH and diabetes models will be explored to help produce a new SDOH model that encompasses the factors involved in diabetes risk and management.

In the context of diabetes, J. O. Hill et al. (2013) describes the socioecological determinants of obesity and diabetes risk. The socioecological determinants of prediabetes and T2DM include the biological and geographic factors and the built environment (J. O. Hill et al., 2013). This perspective goes beyond individual factors, so that various influences of home, work, school, and community environments and the influence of public policies on behaviour can be examined (J. O. Hill et al., 2013). The J. O. Hill et al. (2013) model has several levels and sectors of influence. The model begins with energy balance, but then considers individual factors (demographics, psychosocial characteristics, gene-environment interactions) connected to food and beverage intake and physical activity that affect that balance. The next level/sector is behavioural settings, such as the community, worksite, health care, school and childcare, and home contexts in which the individuals live and work. Sectors of influence is the next highest level/sector, which includes the government, public health, health care, agriculture, education, media, land use and transportation, communities, foundation, and industries (food, beverage, restaurant, food retail, physical activity, leisure and recreation, and entertainment). The highest level/sector of the model is the social norms and values (J. O. Hill et al., 2013). The model illustrates a hierarchical order and a broad range of levels and sectors of influence on diabetes risk.

Another model by J. Hill, Nielsen, and Fox (2013) proposes that the influence of SDOH (including education, income, housing, and access to healthy food) on T2DM is crucial to the disease's development and advancement. J. Hill et al. (2013) indicate that the prevalence and incidence of T2DM appears to be classified by social status, because people with lower income and lower education have four times the risk of developing diabetes compared to people with greater advantage. Accordingly, the SDOH warrant attention for the management of chronic conditions because the SDOH are a significant obstacle to the health of the public (J. Hill et al., 2013). The sociobiological cycle of diabetes proposes that the development of the disease is cyclical, as it can cause and lead to detrimental consequences. Material deprivation, described as the deficiency of resources required to fulfil the basic standards of health, and poverty, could be crucial to this cycle because people who are disadvantaged may be continuously struggling and experience increased chronic stress levels, leading to psychological and biological reactions. For instance, chronic stress can result in higher depression and anxiety, diminished self-esteem, and lower energy and ambition. This can increase the probabilities of choices and behaviours being made that are damaging to the self (such as smoking tobacco, high alcohol consumption, and intake of unhealthy foods). Chronic stress can be physically expressed as a negative outcome of allostatic load such as having higher blood glucose levels, blood pressure, and cortisol and also, compromise the person's potential to successfully handle stressors later in life. As time progresses, the physiologic responses combined with the disadvantageous psychological reactions and the choices and behaviours of the individual can exacerbate the risk of developing T2DM and obesity. Also, it should be clarified that the interactions between individuals and their environment are reciprocal because individuals are able to form and be affected by their environment. Consequently, ameliorating the management and prevention of chronic conditions involves a "coordinated, multilevel approach" (J. Hill et al., 2013).

A paper by Raphael et al. (2003) also describes the existing literature about the social determinants of T2DM and the issues that health researchers and employees currently face, which allows for inquiries to be made about the antecedents of T2DM's incidence and the factors affecting the management of the disease. T2DM predominantly affects people with low income, such as indigenous Canadians. Raphael et al. (2003) highlights the SDOH framework by Brunner and Marmot, which explains the possible contributions of these views for understanding the incidence of T2DM and how to manage it. The framework also pinpoints the overlooked aspects that are needed to theorize T2DM's causes and the associated challenges with managing it (Brunner & Marmot, 1999). The model consists of "proximal causes of morbidity, mortality, and wellbeing, which include pathophysiological changes and organ damage, neuroendocrine and immune responses" (Brunner & Marmot, 1999; Raphael et al., 2003). Slightly more distal are the health behaviours such as nutrition and diet, exercise, and tobacco use. Even more distal factors include psychological reactions to employment and social environments (Brunner & Marmot, 1999). This model recognizes the direct consequences of material resources that accrue throughout life on mortality, morbidity, and wellbeing (Brunner & Marmot, 1999).

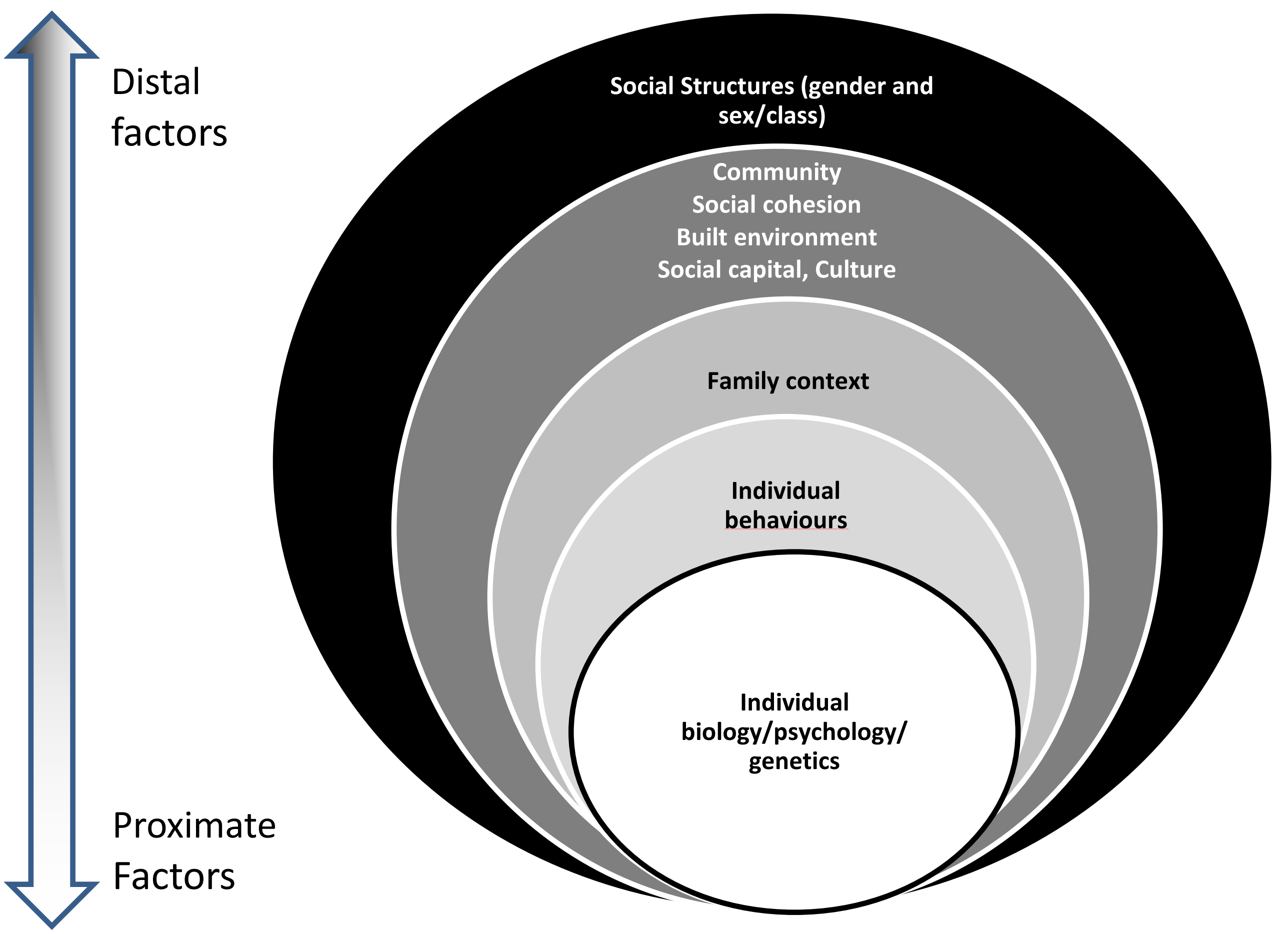
Health researchers, public health employees, and disease-centred associations, infrequently think of the more distal factors when examining population health, while the more proximal factors are frequently accounted for in diabetes and health research. This model identifies that the determinants affect the incidence and prevalence of the disease in communities and the determinants play a role in the disease's effective management. The social determinants affect how behaviours that contribute to the incidence of the disease and effective diabetes management are embraced. Although, evidence indicates that SDOH, particularly, those attributable to the lack of material resources, could have a direct effect on the disease's incidence and management via several pathways, including psychological, biological, and social, over the life course (Brunner & Marmot, 1999; Raphael et al., 2003).

Furthermore, recent research has indicated that the role of the SDOH and T2DM requires attention in order to correct the outcomes of T2DM. Often the research and medical approaches have concentrated their efforts on the person and creating health advancements that are transient (Clark & Utz, 2014). However, more current research has acknowledged that the SDOH and diabetes as well as personal factors must be addressed to improve the current health outcomes. The factors external to the person, which are the SDOH and diabetes, are the social-ecological factors that are influencing health. An individual, their social community, and their culture and environment make up the framework for the SDOH. Overall, this framework includes culture, the environment, education, labour conditions, health care access, economic stability, and the built environment/community infrastructure. Essentially, determinants that are "external or upstream", like social support and community elements, influence a person's health and self-management of T2DM (Clark & Utz, 2014). Therefore, the SDOH's impact must be examined to allow for creation of successful interventions, decreased burden of diabetes, and better health outcomes (Clark & Utz, 2014).

It is acknowledged that the social and economic factors are associated with health and that the disparities in social and economic circumstances promote further disparities in health (Schulz et al., 2005). Viewing diabetes in relation to the SDOH increases the breadth of the determinants that can be investigated in addition to the personal factors such as diet and exercise level. Schulz et al.'s (2005) model for the city of Detroit places the focus on the social determinants, as it recommends that research and interventions consider social and economic policies, the social and physical environments, and the consequences of the policies and behavioural environments, social exchanges, and biological health markers (Schulz et al., 2005). This model can display that the accessibility to nutritious foods impacts a person's dietary choices, as well as the public policies that fund manufacturing of certain food items (that may be unhealthy). This shows that recognizing the relationships between social, economic, and biological aspects can aid health professionals to consider the repercussions of stepping in at different times in these relationships (Schulz et al., 2005).

In addition, the SDOH and race and socioeconomic status (SES) play a role in the SDOH framework by Schulz et al. (2005) for Detroit, Michigan. The racial health inequalities are largely diminished when socioeconomic status (SES) is accounted for, but a number of racial variances in health continue to persist (Schulz et al., 2005). Hence, the social determinants of racial disparities in diabetes risk for Detroit consists of fundamental, intermediate, and proximate factors and the outcomes. Fundamental factors include race-based segregation by residence and the local economic setting (Schulz et al., 2005). Intermediate factors include stressful life conditions (financial state), built environment (walkability, fresh produce availability, safeness, fast food franchise locations), the social environment (the police's ability to keep peace, social assistance with dietary behaviours, level of physical activity, job conditions, and time for leisure), and the educational prospects and access to information (Schulz et al., 2005). Proximate factors are the physiological reactions to stress, dietary behaviour, level of physical activity, and an understanding of the association between diet and physical activity to diabetes (Schulz et al., 2005). The outcomes are the individual's body weight/obesity, fitness, and diabetes risk (Schulz et al., 2005). Schulz et al.'s (2005) framework and study established that focusing on the social factors over the numerous levels of the model is imperative to complete.

Figure 1: Hierarchical model of Social Determinants and T2DM Risk



The components of these several models for the SDOH and diabetes risk can be combined to create a framework that broadly incorporates the various biological, social, and economic factors that range from proximal to distal in relation to the individual, as shown in Figure 1. The model will consist of hierarchal levels that operate downstream to upstream, contain stress pathways, and indicate the relationships between factors that are reciprocal, which will express the cyclical nature of the social determinants and diabetes risk.

There are several potential pathways, such as obesity, health literacy, and food insecurity, that connect the SDOH to diabetes, but they will not be a central focus of this study. Food insecurity is important to account for, but it is not available in the survey for all provinces and health literacy is not directly measured. Obesity is not a behaviour and once it is controlled for in the model, a lot of predictive power will be removed for T2DM. These mediators are found at in the middle level of the model. Income works through food insecurity to affect T2DM risk. In the same way, a majority of the behavioural variables that we include in the models, such as smoking, are factors that work through income. For the remainder of the research, we are interested in looking at socioeconomic status and gender. We acknowledge that obesity, health literacy, and food insecurity are mediators between gender and socioeconomic status, but we will not focus on them or include them directly in the model. These mediators are important, but we do not have complete information on them in the survey and consequently, the focus of this study will be on the effects of the structural dimensions of gender and socioeconomic status.

3.2 Intersectional Approaches to Sex and Gender

The social determinants of health framework will be augmented by an intersectional view on the relationship between sex and gender and other dimensions of risk, particularly low income (Crenshaw, 1991). Intersectionality arose from concerns that “mainstream” approaches to gender inequality failed to adequately consider that African-American women experienced different forms of gender oppression from white women (Collins, 1990). Applied to health inequalities, intersectionality provides a lens that can be used generate questions about how risk or experience of illness might be shaped both by gender and by other social dimensions simultaneously (Hankivsky, 2011). Critically, intersectionality focuses on how these resulting inequalities are produced and reproduced by power relations in intersecting systems, such as gender/patriarchy and class/capitalism (López & Gadsden, 2016). In the case of diabetes, an intersectional perspective can help to unpack the ways that the lives of low income women and men are potentially shaped not only by social class, but also by gender, to result in differential risks for diabetes.

The integration of intersectionality frameworks into quantitative research has been challenging, owing to the epistemological foundations of much of the feminist literature (Hankivsky, 2011). However, there have been some useful articulations of intersectional approaches to quantitative modelling, including work in health research. Scott and Siltanen (2017) have described how a focus on interaction terms in regression models can be used to relate quantitative models to intersectionality-related research questions. In the context of health research, including interactions between elements of social location (e.g. gender, low income conditions) can be used to identify the differential risks of a particular health outcome for those located in each of the possible combinations of these locations (Veenstra, 2011). Using this approach, the additive main effects for these social location variables in the regression model indicate their overall relationships to the outcome, while the multiplicative interaction effects indicate the degree to which one is modified by the other. This allows the risks for low income women, to be compared to both non-low income women as well as to men, both low income and not (Veenstra, 2011).

Scott and Siltanen (2017) propose that this approach can be more closely aligned with intersectionality theories if interaction terms are extended to three-way interactions, in which one variable is a "contextual" variable. This, they argue, would help to move the analysis closer to one in which it is possible to understand the role of context in structuring inequalities. Importantly, "context" need not be geographic or physical context, but could also be social contexts such as educational pathways, such an examination of gender differences in earning for those with apprenticeships and those with other types of trade education. In this case, educational pathways serve as the structuring context for gender differences in earnings, rather than an element of social location as such. If data permit, these contextual effects could also be examined using models stratified by context, or in hierarchical (random effects) models, rather than using interactions in single-level (fixed-effects) models (Scott & Siltanen, 2017).

In addition to considering the importance of social location/identity in disease risk and context in structuring that risk, intersectionality approaches to health can direct our attention to the processes that lead to, or "amplify" differences between groups (Bauer, 2014). As described above, in the case of diabetes processes that potentially lead to gender and income differences in risk include differences in the experience of stress, as well as behavioural differences in diet and physical activity (Schulz et al., 2005). An intersectional approach to understanding how T2DM risk is structured by both sex and gender and socioeconomic status should therefore consider how these processes might "amplify" these differences.

3.3 Research Questions

Drawing from both social determinants of health and intersectionality frameworks, we have three main research questions that aim to improve our understanding of the relationship between socioeconomic status, gender, and other sociodemographic and behavioural factors, in diabetes risk.

We first ask whether there are significant differences between men and women, in the relationship between measures of socioeconomic position (income, education and current occupation) and T2DM risk and age at onset of diabetes. This question addresses Scott and Siltanen's (2017) the first stage of an intersectionality analysis by asking if these two dimensions of social identity-sex/gender and socioeconomic position, interact to structure the risk of T2DM.

Second, we will examine whether there is evidence of these differences being produced in specific *contexts*. In particular, we are interested in the role of family context (Figure 1) in the differences in risk of diabetes for men and women. This will include testing whether the gender differences in diabetes risk are shaped by differences in family and household configuration (e.g. the presence of children, lone-parent or 2-parent families, or single individuals), independent of the role of household income or socio-economic position.

Third, we will examine the observable processes that might be leading to (or "amplifying") observed differences in diabetes risk. For example, are sex and gender differences in the relationships between socioeconomic position and T2DM "explained" by differences in health-related behaviours (physical activity, fruit and vegetable consumption, smoking, alcohol consumption, preventive health care use)? Are the differences in the relationships between socioeconomic position and T2DM outcomes for men and women potentially due to differences in health-related behaviours or measures of stress?

4.0 Methods

4.1 Canadian Community Health Survey (CCHS) Data

The CCHS is a national, cross-sectional survey intended to capture the health of the Canadian population with geographic representation at the Health Region level (Statistics Canada, 2016). The survey is conducted in all provinces and territories and is representative of the Canadian population excluding those living on First Nations reserves, in residential institutions such as prisons, and full-time Canadian Forces members (Statistics Canada, 2016). The CCHS was accessed through the Statistics Canada Research Data Centres (RDC) program.

The combined CCHS 2015 and 2016 Annual Components were used to examine the correlates of T2DM. The combined 2-year sample of the CCHS is roughly 120,000 respondents aged 18 and older (Statistics Canada, 2016). Applying the current prevalence of approximately 9%, it was expected that just fewer than 11,000 respondents had indicated having diabetes, and that 90% of these had T2DM (approximately 10,000). Overall prevalence of low income in 2015, according to the 2016 census, was 14.2% (Statistics Canada, 2017c), suggesting about 17,000 individuals aged 18 and older in the 2015 and 2016 CCHS sample had household incomes at or below the Low Income Measure. Under the conservative assumption that 10% of those in low income households were identified as having T2DM, that gave us an expected sample of 1,700 individuals living in low income with diabetes, roughly 850 males and 850 females.

4.2 Measures

The CCHS asked whether the respondent has diabetes (CCC_Q095), and also the age at which they were first diagnosed with the disease (CCC_Q100). The dataset also included an indicator of whether the respondent has type 1 or type 2 diabetes (CCCDVDIA), based on factors such as age at initiation, whether they reported taking insulin for diabetes, whether they have been pregnant, and other indicators, using the Ng-Dasgupta-Johnson algorithm (Ng, Dasgupta, & Johnson, 2008).

We used these variables to create two main outcome measures (Table 1). The first is whether the respondent has T2DM, which was operationalized as a binary indicator (1= has T2DM, 0 = does not have T2DM). The second was an indicator of the age at which the respondent was first diagnosed with T2DM. We assumed that those identified as having T2DM were first diagnosed with T2DM (and not type 1 diabetes). Based on the distribution of the data, the outcome was coded as a series of age categories 18 to 75 years old (e.g. 18-24, 25-30, etc.), to be used as ordinal logistic regression outcomes. This outcome was treated as continuous (age at diagnosis in years). 9050 respondents aged 12 to 17 years old were deleted from the dataset. 350 respondents were recoded as not stated and were coded to T2DM = 0.

Demographic, socioeconomic status (SES), geographic, health behaviours, and stress variables were selected as measures for analysis. The main independent variables included sex/gender (DHH_SEX) and distribution of household income – provincial level (INCDVRPR). The CCHS asks a single sex/gender question and allowed only a binary response (Rich-Edwards, Kaiser, Chen, Manson, & Goldstein, 2018). As such, we cannot be sure whether respondents' answers reflected biological sex or gender identity. As both biology and social differences are potentially important, we consider this when interpreting the models and if any observed differences appear to be more likely to be due to social or biological effects (Rich-Edwards et al., 2018). With the consideration of limitation of there only being one variable in the CCHS for sex and gender, we will be interpreting the effects of gender, rather than sex for the remainder of the study due to they intricate manner in which gender is institutionalized in society (Canadian Institutes of Health Research, 2020).

The survey collects annual household income, from all sources. For a majority of respondents (69.0% in 2015), this information was taken from linked tax records, and was self-reported for the remainder. Household income was used to divide the sample into categories, income deciles (e.g. Decile 1 (lowest) to Decile 10 (highest)).

A new dataset for analysis was created to include the variables selected to be measured. Cases that had valid answers for all of the variables were used. This meant that some respondents who answered “not stated”, “don’t know”, or “refused” were deleted from the dataset or placed into a separate new category. As a result, approximately 2000 women that answered “refusal”, “don’t know”, and “not stated” for pregnant (MAC_025) were deleted from the dataset. Approximately 60 people who did not respond to type of smoker (SMK_005) were deleted. 1150 respondents who had a proxy (ADM_PRX) answer for them were also removed. In addition, the respondents who were “not stated” for the distribution of household income – provincial (INCDVRPR) were deleted from the dataset. Cases with “don’t know” and “refusal” responses were removed from the dataset from perceived life stress (GEN_020). The respondents deleted from the health behaviour variables included 1850 people who answered “not stated” for physical activity indicator (D) (PAADVACV), 500 people who were “don’t know”, “refusal”, and “not stated” for drank alcohol – Frequency – 12 months (ALC_015), 500 cases who were “not stated” for the type of drinker – 12 months (D) (ALCDVTTM), and 3100 people who were “not stated” for daily consumption – fruits and vegetables (FVCDVTOT). Among the SES variables, those whose working status last week (D) LBFDVWSS was indicated as a “valid skip”, “don’t know”, “not stated”, or “refusal” were deleted from the dataset.

Respondents living in the Canadian territories were not included in the analysis dataset, because of small numbers. Corrections steps according to the Statistics Canada CCHS 2015/16

Errata were followed for EHG2DVR9 and EHG2DVR3 (see appendix for syntax correction steps). There were no correction steps provided by Statistics Canada for the variable SDCDVCGT, which was noted as having a coding error, but which would not affect our analysis.

Several of the demographic, socioeconomic status (SES), geographic, health behaviour, stress, obesity, and healthcare utilization variables included in the dataset were recoded in order to use them as measures. The new demographic variable, AGEGROUP, was created from DHH_AGE with eleven categories. The demographic variable, SDCDVCGT (cultural/racial background), was recoded as BACKGROUND and reduced to 11 categories: White only, East Asian, South Asian, West Asian/Arab only, Southeast Asian, Black only, Latin America, Filipino only, Other/multiple racial or cultural origins, Aboriginal, and Not stated. A new SES variable, economic family status (household type), HOUSEHOLD, was formed from DHHDVECF [Economic family status (household type) - (D)] and grouped into 5 categories: Couple (member) (alone, with or without children, others), Child in a couple family, Lone parent (male or female – aged 25+yo and others), Child in a lone parent family (males or females, less than 25 yo and others), and Unattached individual alone and with others, other households and not stated.

An “OCCUPATION” variable was created from LBFDVOCG (occupation group) including the categories: Management, Business, finance and administration, Natural and applied sciences and related, Health, Education, law, social/community/government services, Art, culture, recreation, and sport, Sales and service, Trades, transport and equipment operators and related, Natural resources, agriculture, and related production, Manufacturing and utilities, and Not working. An EDUCATION variable was made from EHG2DVR9 (Respondent 9 levels - highest level of education) and was reduced to six categories, including a “not stated” category.

Health behaviour variables that were recoded were FRUITVEGDAILY, which was formed from FVCDVTOT (Daily consumption - fruits and vegetables) and included low, medium, and high fruit/vegetable daily consumption, and TALDVUSE (Alternative tobacco product usage) became ALTTOBACCO with the categories "Has used an alternative tobacco product", "Has not used an alternative tobacco product". STRESS was created from GEN_020 (Perceived life stress) and included four categories: Not at all stressful, Not very stressful, A bit stressful, and Quite a bit stressful and extremely stressful. Lastly, CHPDVMDC was recoded as CONSULTMEDDOC and included 0 to 31 and higher and not stated consultations with medical doctor/other specialists.

4.3 Analyses

In general, the main research questions were addressed using multivariate logistic regression techniques for binary or ordinal outcome variables (Tabachnick & Fidell, 2013). The analytical strategy involved creating two sets of models; one for each of the dependent variables, whether diagnosed with diabetes and the age of diabetes.

The set of first models used binary logistic regression to predict the log-odds that an individual was diagnosed with T2DM. The first model included age as a control variable, sex and income, in order to test whether sex and gender and income have independent effects, and included an interaction of sex and gender and income, in order to test whether the effects of income are different for males and females. Specifically, the first model included sex and T2DM status. The second model included T2DM status, sex, and age. The third model T2DM status, sex, age, and income. The fourth model included T2DM status, sex, age, income, and an interaction between sex and income. The interaction was significant and therefore, subsequent models were stratified by gender, meaning that separate models were estimated for males and for females. Subsequent models included other socioeconomic status variables (education, working status last week, occupation group, economic family status household), sociocultural group, and other potentially important factors. The fifth model included males only, T2DM status, age, income, education, household, background, occupation, and working status last week. The sixth model included females only, T2DM status, age group, income, education, household, background, occupation, and working status last week. Models seven to nine were comprised of the geographic indicators GEODVUR2 (population centre or rural area) and GEO_PRV (province of respondent) in addition to sex (both sexes, males only, or females only), age, and T2DM status. Models ten to 12 included the health behaviour indicators type of smoker (SMK_005), alternative tobacco product usage (ALTTOBACCO), physical activity indicator (PAADVACV), type of drinker (ALC_015), frequency of total daily vegetable/fruit consumption (FRUITVEGDAILY), and perceived life stress (STRESS) as well as sex (both sexes, males only, or females only), age, and T2DM status. Models 13 to 15 included the social determinants and geographic indicators with the variables sex (both sexes, males only, or females only), age, and T2DM status. Models 16 to 18 involved the social determinants, geographic, and health behaviour indicators with the variables for sex (both sexes, males only, or females only), age, and T2DM status. Models 19 to 21 comprised the social determinants, geographic, health behaviour (excluding ALTTOBACCO) indicators with sex (both sexes, males only, or females only), age, and T2DM status. By modelling the effects of these variables for men and women, separately, we addressed the question of whether low income and other social determinants and behavioural predictors of diabetes had different effects for men and for women.

A second set of models was created to predict the age at diagnosis of diabetes, among those who had been so diagnosed. The subsample for analysis for this question was only those individuals with T2DM. The smaller sample size did not prevent the estimation of separate models for men and women.

Table 1. Summary of Key Variables used from the Canadian Community Health Survey (2015/16)

Question/Variable	**Description**
	Main Outcomes
CCC_Q095	Has diabetes
CCC_Q100	Diabetes- age first diagnosed
CCCDVDIA	Has Type 1 or Type 2 diabetes (derived)
	Sociodemographic Variables
DHH_AGE	Age of respondent
DHH_SEX	Sex (male/female)
SDC_IM3	Landed immigrant status
SDCDVCGT	Cultural/racial background
SDC_015	Aboriginal (First Nations/Métis/Inuk)
	Geographic variables
GEO_PRV	Province/Territory
GEODVUR	Population centre or rural area type
	Socioeconomic Status Variables
EHG2DVR9	Highest level of education
INCDVHH	Annual household income
INCDVRPR	Distribution of household income
FSCDVHFS	Food security (household), derived[1]
DHHDVECF	Economic Family status
LBFDVWSS	Working status last week
LBFDVOCG	Occupation group
	Health Behaviour Variables
SMK_005	Type of smoker
TALDVUSE	Alternative tobacco product use
ALCDVTTM	Type of drinker
PAADVACV	Physical activity indicator
FVCDVGDT	Total daily fruit and vegetable consumption
FVCDVTOT	Frequency of total daily fruit and vegetable consumption
FDCDVAVD	Avoids certain foods for content reasons
	Healthcare utilization and diabetes care
CHPDVMDC	Number of consultations with medical doctor or other specialists
DIA_Q040	Nutrition therapy for diabetics by dietician
DIA_010	Tested for haemoglobin A1C
DIA_020	Feet checked by health professional
DIA_035	Eye exam with pupils dilated
DIA_045	Glucose level checked
DIA_050	Feet checked
	Obesity: Body Mass Index
HWTDVBCC	BMI classification 18 and +

Source: Canadian Community Health Survey (CCHS) 2015–16 Annual Component Master File (Statistics Canada, 2017a)

[1]Not available for Ontario.

Table 2. Summary of Recoded Variables to be used from the Canadian Community Health Survey (2015/16)

Question/Variable	Description of variables	Notes
	Main Outcomes	Recoded from CCCDVDIA
T2DM	Type 2 diabetes status	
	Sociodemographic Variables	Recoded from DHH_AGE
AGEGROUP	Age group	
BACKGROUND	Cultural/racial background	Recoded from SDCDVCGT
	Socioeconomic Status Variables	
EDUCATION	Highest level of education	Recoded from EHG2DVR9
HOUSEHOLD	Economic family household status	Recoded from DHHDVECF
LBFDVWSS	Working status last week	
OCCUPATION	Occupation group	Recoded from LBFDVOCG
	Health Behaviour Variables	
ALTTOBACCO	Alternative tobacco product use	Recoded from TALDVUSE
FRUITVEGDAILY	Frequency of total daily fruit and vegetable consumption	Recoded from FVCDVTOT
	Healthcare utilization and diabetes care	
CONSULTMEDDOC	Number of consultations with medical doctor or other specialists	Recoded from CHPDVMDC
	Obesity: Body Mass Index	
BMI	BMI classification 18 and +	Recoded from HWTDVBCC
	Stress Variable	
STRESS	Perceived life stress	Recoded from GEN_020

Source: Canadian Community Health Survey (CCHS) 2015–16 Annual Component Master File (Statistics Canada, 2017a)

We examined the potential effect of family context in structuring the sex/gender and socioeconomic position effects on T2DM risk, by first estimating three-way interactions, and then separating the sample into different family or household types, and estimating the roles of socioeconomic position and sex/gender, as well as socioeconomic position x sex/gender interactions, separately for each context (Scott & Siltanen, 2017). This approach allowed us to test whether the sex/gender and socioeconomic position differences are mediated by family or household context, and then to examine whether there are different predictors that are important for different contexts. Lastly, we will consider the roles of behavioural variables and stress in producing these differences. We will do this by adding the diet, physical activity, and stress measures to the previously-estimated models (for men and women and for different family contexts). In some models, we expect that interactions between these mechanism variables and sex/gender and socioeconomic position will be tested.

For analysis, weights provided by Statistics Canada were used for all models. Population weights, which were used in the regression models and tables, are constructed to account for under-representation of various subpopulations and therefore present a more accurate representation of the total Canadian population. Statistics Canada also provides a set of "bootstrap" weights, to be used in re-estimation procedures. These weights adjust the estimates of variance for the effects of the clustered and stratified sampling design, without disclosing the sampling plan itself. By re-estimating models using the 1,000 sets of weights provides, and using these iterations to estimate the variability around model parameters or means, the resulting confidence estimates more accurately reflects the sampling design than would treating the data as a simple random sample, and results in more conservative significance tests.

5.0 Results

5.1 Effects of sex/gender and SES on risk of T2DM

Table 3 presents the results of the logistic regression for Models 1 and 2, which predict T2DM by sex/gender and SES variables. Model 1 included sex/gender and age group. Females were significantly lower risk compared to males, and there was a clear age gradient, with risks higher among older age ranges. Model 2 added household income coded into provincial deciles. That model presents clear evidence of a gradient in risk according to income, with those in the lowest income decile having nearly 75% higher risk than those in the median deciles and those in the highest income decile having about half the risk. The effect of being female remained roughly the same as in Model 1, as did the effects of age. Specifically, those between 18 and 55 years old were less likely to report having T2DM, whereas those between 61 and 75 years old were more likely to report having T2DM than the reference group, 56 to 60 year-olds.

Table 3: Logistic regression models predicting Type 2 diabetes by sex/gender, adjusted for age and household income (Canadians aged 18–75 years, 2015–16).

	Model 1 OR (95% CI)	**Model 2** OR (95% CI)
Male†	1.000 (--)	1.000 (--)
Female	0.651* (0.589-0.720)	0.618* (0.560-0.683)
Age		
18 – 24	0.008* (0.003-0.019)	0.006* (0.002-0.016)
25 – 30	0.042* (0.026-0.068)	0.037* (0.023-0.061)
31 – 35	0.088* (0.059-0.132)	0.081* (0.054-0.121)
36 – 40	0.182* (0.129-0.256)	0.169* (0.120-0.239)
41 – 45	0.320* (0.245-0.417)	0.299* (0.230-0.389)
46 – 50	0.524* (0.417-0.659)	0.508* (0.404-0.638)
51 – 55	0.659* (0.546-0.795)	0.665* (0.550-0.805)
56 – 60 †	1.000 (--)	1.000 (--)
61 – 65	1.266* (1.076-1.490)	1.233* (1.047-1.453)
66 – 70	1.633* (1.397-1.908)	1.474* (1.257-1.728)
71 – 75	2.067* (1.759-2.430)	1.812* (1.534-2.140)
Household income – Provincial deciles		
Decile 1	-	1.748* (1.394-2.192)
Decile 2	-	1.425* (1.154-1.760)
Decile 3	-	1.136 (0.920-1.404)
Decile 4	-	1.196 (0.968-1.477)
Decile 5†	-	1.000 (--)
Decile 6	-	1.023 (0.805-1.301)
Decile 7	-	0.832 (0.663-1.044)
Decile 8	-	0.746* (0.598-0.931)
Decile 9	-	0.702* (0.572-0.862)
Decile 10	-	0.543* (0.435-0.678)
Model fit characteristics		
N	77681	77681
DF	11	20
-2 Log L	30623.867	30199.483
C statistic	0.756	0.767

Note: Data from the 2015–16 CCHS. Variance estimates calculated using bootstrapped weights.
† Reference category. * Values are significant at p<0.05.

As described above, there are a number of factors that potentially mediate or moderate the relationships between gender, socioeconomic position and T2DM. We therefore added other socioeconomic status, geographic, and demographic variables to the model, in order to test for their independent effects, as well as to see whether they reduced the effects of gender or income, in the analysis.

The results of this model are presented in Table 4. Again, females were less likely to report having T2DM than were males. The odds ratio for females, with 95% confidence interval, was 0.578 (0.521-0.642). As with the previous models, age remained an important predictor of T2DM. For ages 61 to 75 years old, the odds ratios were greater than one, which indicated that those at older ages are more likely to report having T2DM, when compared to those aged 56 to 60 years old.

Cultural/racial background was significantly associated with T2DM, with several categories at higher risk, compared to the reference group of “White only” identification. People reporting being Aboriginal (OR=1.478, 95% CI=1.169-1.869), Black only (OR=2.521, 95% CI=1.646-3.861), Filipino only (OR=2.517, 95% CI=1.509-4.196), other/multiple racial or cultural origins (OR=1.553, 95% CI=1.070-2.256), South Asian (OR=3.336, 95% CI=2.436-4.567), and West Asian/Arab only (OR=1.828, 95% CI=1.181-2.829) were more likely to report a diagnosis of T2DM in comparison to White only. East Asian, Latin America, and Southeast Asian, which were not significantly different from those identifying as “White” only, controlling for the other variables in the model (Table 4).

Table 4: Logistic regression models predicting Type 2 diabetes by sex/gender and socioeconomic status variables (Canadians aged 18–75 years, 2015–16).

	OR (95% CI)		**OR (95% CI)**
Male†	1.000 (--)	*Education*	
Female	0.578* (0.521-0.642)	Grade 13 and below	1.315* (1.119-1.545)
Age		Secondary School †	1.000 (--)
18 – 24	0.005* (0.002-0.014)	Less than Bachelor's	0.928 (0.820-1.051)
25 – 30	0.037* (0.023-0.060)	Bachelor's	0.652* (0.544-0.781)
31 – 35	0.083* (0.055-0.125)	Above Bachelor's	0.562* (0.438-0.721)
36 – 40	0.172* (0.120-0.245)	Not stated	1.023 (0.695-1.505)
41 – 45	0.298* (0.228-0.388)	*Economic family household*	
46 – 50	0.507* (0.399-0.646)	Couple †	1.000 (--)
51 – 55	0.680* (0.560-0.825)	Child in a Couple Family	0.998 (0.861-1.156)
56 – 60†	1.000 (--)	Lone Parent	1.288* (0.901-1.842)
61 – 65	1.230* (1.040-1.455)	Child in Lone Parent Family	1.106 (0.789-1.551)
66 – 70	1.430* (1.203-1.701)	Unattached Individual/other	1.038 (0.925-1.166)
71 – 75	1.699* (1.416-2.039)	*Cultural/Racial Background*	
Household income – Provincial deciles		Aboriginal	1.478* (1.169-1.869)
Decile 1	1.438* (1.143-1.809)	Black Only	2.521* (1.646-3.861)
Decile 2	1.210 (0.974-1.502)	East Asian	1.014 (0.663-1.551)
Decile 3	1.025 (0.825-1.275)	Filipino Only	2.517* (1.509-4.196)
Decile 4	1.145 (0.926-1.416)	Latin America	0.769 (0.379-1.557)
Decile 5†	1.000 (--)	Not stated	2.090 (0.924-4.730)
Decile 6	1.089 (0.860-1.379)	Other/multiple	1.553* (1.070-2.256)
Decile 7	0.925 (0.732-1.169)	South Asian	3.336* (2.436-4.567)
Decile 8	0.871 (0.695-1.091)	Southeast Asian	0.900 (0.420-1.925)
Decile 9	0.861 (0.698-1.061)	West Asian/Arab only	1.828* (1.181-2.829)
Decile 10	0.738* (0.588-0.928)	White Only †	1.000 (--)

Table 4, continued

	OR (95% CI)		OR (95% CI)
Working Status last week		*Urban/rural*	
Worked at a job/business †	1.000 (--)	Urban †	1.000 (--)
Absent from work	1.317* (1.009-1.719)	Rural Area	0.910 (0.824-1.004)
Did not have a job	1.399 (0.784-2.497)	*Province*	
Occupation		Alberta	0.818* (0.695-0.963)
Art, culture, recreation, sports	1.070 (0.481-2.383)	British Columbia	0.734* (0.617-0.875)
Business, finance, administration	1.335 (0.735-2.423)	Manitoba	0.852 (0.691-1.050)
Education, law, government	1.096 (0.592-2.027)	New Brunswick	1.182 (0.953-1.466)
Health	1.427 (0.748-2.722)	Newfoundland and Labrador	1.084 (0.893-1.317)
Management	0.951 (0.512-1.767)	Nova Scotia	1.381* (1.134-1.682)
Natural & applied sciences	0.798 (0.410-1.554)	Ontario †	1.000 (--)
Natural resources, agriculture	0.976 (0.494-1.931)	Prince Edward Island	1.072 (0.817-1.406)
Not working or missing †	1.000 (--)	Quebec	0.900 (0.793-1.021)
Manufacturing and utilities	0.849 (0.436-1.650)	Saskatchewan	1.014 (0.827-1.243)
Sales and services	1.159 (0.644-2.088)		
Trades, transport operators	1.191 (0.650-2.185)		
N	77681	-2 Log L	29455.394
DF	61	C statistic	0.779

Note: Data from the 2015–16 CCHS. Variance estimates calculated using bootstrapped weights.
† Reference category. * Values are significant at p<0.05

The SES variables included in the model were education, economic family household, household income, working status last week, and occupation. The categories for education that were significantly associated with T2DM were grade 13 and below (OR=1.315, 95% CI=1.119-1.545), Bachelor's degree (OR=0.652, 95% CI=0.544-0.781), and above Bachelor's degree (OR=0.562, 95% CI=0.438-0.721), in reference to the category secondary school graduation, no post-secondary. The respondents from grade 13 and below had a greater likelihood of reporting T2DM when compared to the reference group and those with Bachelor's degree and above Bachelor's degree, who were both at nearly half the risk for T2DM in comparison to the respondents in secondary school graduation, no post-secondary.

Relative to those living as couples, lone parents were at significantly higher risk of T2DM. Lone parents had an odds ratio of 1.288 with a 95% CI=0.901-1.842, signifying that they are more likely to report having T2DM than members of the reference category, those living in couples with or without children.

Table 6 also shows some relationship of income to T2DM, independent of the other SES variables in the model. Those in decile 1 (OR=1.438, 95% CI=1.143-1.809) were at higher risk of reporting having T2DM when compared to decile 5 and decile 10 (OR=0.738, 95% CI=0.588-0.928) was less likely to report having T2DM than decile 5. The variable, working status last week, showed that being absent from work (OR=1.317, 95% CI=1.009-1.719) had significantly higher risk of T2DM than those who were working. None of the occupation dummy variables were found to be at significantly different risk to T2DM than those who were not working or missing.

Urban or rural residence was not significantly associated with T2DM. Alberta and British Columbia residents were less likely to have T2DM than those living in Ontario, controlling for other variables in the model (Alberta: (OR=0.818, 95% CI=0.695-0.963); British Columbia: (OR=0.734, 95% CI=0.617-0.875)). Those living in Nova Scotia were at significantly higher risk than Ontarians (OR=1.381, 95% CI=1.134-1.682).

5.2 Effects of health behaviours and stress on risk of T2DM

In the second set of models, presented in Table 5, health behaviours and stress were added, along with the variables in the first models. The health behaviour variables in this model were type of smoker, frequency of drinking alcohol, alternative tobacco product usage, physical activity indicator, and fruit/vegetable consumption.

Results for the type of smoker showed no significant effects of smoking, compared to non-smokers. For frequency of drinking alcohol, 2 to 3 times a month (OR=0.752, 95% CI=0.617-0.917), 2 to 3 times a week (OR=0.466, 95% CI=0.397-0.546), 4 to 6 times a week (OR=0.347, 95% CI=0.268-0.448), every day (OR=0.336, 95% CI=0.256-0.440), and once a week (OR=0.591, 95% CI=0.495-0.705) were all significantly associated with lower risk of T2DM when compared to those who did not drink at all. Several categories of use of alcohol frequency (2 to 3 times a month, 2 to 3 times a week, 4 to 6 times a week, every day, and once a week) were slightly protective against T2DM, compared to not drinking at all, controlling for the other variables in the model. No categories of alternative tobacco use were significantly different in terms of risk of T2DM when compared with the reference category, not using any alternative tobacco products (Table 5).

Table 5: Logistic regression models predicting Type 2 diabetes by sex/gender, socioeconomic status variables and health behaviours/stress (Canadians aged 18–75 years, 2015–16).

	OR (95% CI)		**OR (95% CI)**
Male†	1.000 (--)	*Education*	
Female	0.485* (0.433-0.543)	Grade 13 and below	1.189* (1.008-1.402)
Age		Secondary School †	1.000 (--)
18 – 24	0.006* (0.002-0.015)	Less than Bachelor's degree	0.959 (0.846-1.088)
25 – 30	0.040* (0.025-0.066)	Bachelor's degree	0.715* (0.593-0.861)
31 – 35	0.087* (0.057-0.131)	Above Bachelor's	0.610* (0.472-0.788)
36 – 40	0.175* (0.123-0.249)	Not stated	1.029 (0.693-1.529)
41 – 45	0.299* (0.228-0.390)	*Economic family household*	
46 – 50	0.506* (0.398-0.645)	Couple †	1.000 (--)
51 – 55	0.691* (0.570-0.839)	Child in a Couple Family	0.947 (0.817-1.098)
56 – 60†	1.000 (--)	Lone Parent	1.141 (0.789-1.650)
61 – 65	1.253* (1.052-1.491)	Child in Lone Parent Family	1.073 (0.763-1.510)
66 – 70	1.451* (1.216-1.732)	Unattached Individual/other	1.015 (0.901-1.144)
71 – 75	1.656* (1.374-1.996)	*Cultural/Racial Background*	
Household income – Provincial deciles		Aboriginal	1.459* (1.152-1.846)
Decile 1	1.266 (0.999-1.605)	Black Only	2.084* (1.362-3.190)
Decile 2	1.091 (0.877-1.358)	East Asian	0.775 (0.497-1.207)
Decile 3	0.953 (0.764-1.188)	Filipino Only	1.858* (1.112-3.103)
Decile 4	1.109 (0.893-1.376)	Latin America	0.713 (0.355-1.432)
Decile 5†	1.000 (--)	Not stated	1.743 (0.768-3.959)
Decile 6	1.103 (0.866-1.407)	Other/multiple	1.296 (0.888-1.891)
Decile 7	0.987 (0.780-1.247)	South Asian	2.543* (1.849-3.497)
Decile 8	0.933 (0.741-1.175)	Southeast Asian	0.700 (0.327-1.497)
Decile 9	0.945 (0.761-1.172)	West Asian/Arab only	1.446 (0.927-2.256)
Decile 10	0.854 (0.677-1.077)	White Only †	1.000 (--)

Table 5, continued

	OR (95% CI)		OR (95% CI)
Working Status last week		*Urban/rural*	
Worked at a job/business †	1.000 (--)	Population Centre †	1.000 (--)
Absent from work	1.254 (0.956-1.644)	Rural Area	0.884* (0.798-0.978)
Did not have a job	1.426 (0.809-2.512)	*Province*	
Occupation		Alberta	0.799* (0.677-0.944)
Art, culture, recreation, sports	1.199 (0.545-2.640)	British Columbia	0.780* (0.654-0.929)
Business, finance, administration	1.329 (0.742-2.379)	Manitoba	0.839 (0.680-1.037)
Education, law, government	1.107 (0.609-2.009)	New Brunswick	1.028 (0.825-1.280)
Health	1.355 (0.717-2.561)	Newfoundland and Labrador	0.980 (0.803-1.195)
Management	0.964 (0.527-1.761)	Nova Scotia	1.252* (1.027-1.528)
Natural & applied sciences	0.758 (0.393-1.462)	Ontario †	1.000 (--)
Natural resources, agriculture	0.984 (0.502-1.928)	Prince Edward Island	1.003 (0.758-1.326)
Not working or missing †	1.000 (--)	Quebec	0.951 (0.833-1.086)
Manufacturing and utilities	0.825 (0.430-1.581)	Saskatchewan	0.967 (0.785-1.191)
Sales and services	1.141 (0.643-2.027)	*Physical Activity Indicator*	
Trades, transport operators	1.183 (0.656-2.132)	No physical activity minutes	1.554* (1.371-1.761)
Type of Smoker		Physically active at/above †	1.000 (--)
Daily	0.925 (0.784-1.091)	Physically active below	1.117 (0.985-1.266)
Not at all †	1.000 (--)	*Fruit/Vegetable Daily Consumption*	
Occasionally	0.866 (0.644-1.164)	Low consumption	1.004 (0.899-1.121)
Drank Alcohol - Frequency		Medium consumption †	1.000 (--)
2 to 3 times a month	0.752* (0.617-0.917)	High consumption	0.708* (0.519-0.965)
2 to 3 times a week	0.466* (0.397-0.546)	*Perceived Life Stress*	
4 to 6 times a week	0.347* (0.268-0.448)	A bit stressful †	1.000 (--)
Every day	0.336* (0.256-0.440)	Not at all stressful	0.853* (0.734-0.992)
Less than once a month	1.153 (0.997-1.334)	Not very stressful	0.761* (0.674-0.859)

Table 5, continued

	OR (95% CI)		OR (95% CI)
Once a month	0.835 (0.691-1.010)	Quite a bit stressful and extremely stressful	1.078 (0.934-1.244)
Once a week	0.591* (0.495-0.705)		
Never †	1.000 (--)		
N	77681	-2 Log L	28641.531
DF	77	C statistic	0.799

Note: Data from the 2015–16 CCHS. Variance estimates calculated using bootstrapped weights.
*† Reference category. * Values are significant at $p<0.05$*

For physical activity indicator, reporting no physical activity minutes (OR=1.554, 95% CI=1.371-1.761) and physically active below (OR=1.117, 95% CI=0.985-1.266) were significantly associated with T2DM when compared with being physically active at/above recommended level from Canada's Physical Activity Guide (CPAG). Finally, respondents reporting "high" daily fruit and vegetable consumption were at lower risk for reporting having T2DM than those reporting medium consumption.

The stress variable indicated that when compared to those reporting that life was "a bit stressful" or "not at all stressful" (OR=0.853, 95% CI=0.734-0.992) and "not very stressful" (OR=0.761, 95% CI=0.674-0.859) were significantly associated with T2DM. The respondents that answered not at all stressful and not very stressful were at lower risk for reporting having T2DM when compared to the reference group of a bit stressful.

After the behavioural and stress variables were added to the models, sex/gender remained significantly associated with T2DM, once health behaviour and stress variables were added to the models (OR_{female} = 0.485; 95% CI=0.433-0.543). Education remained significant as well. Those with Grade 13 and below (OR=1.189, 95% CI=1.008-1.402) had higher odds of T2DM, compared to those with secondary school, while those with a bachelor's degree (OR=0.715, 95% CI=0.593-0.861), and or higher degree (OR=0.610, 95% CI=0.472-0.788) had higher odds.

None of the categories in economic family household when compared to couple (member) (alone, with or without children, others) were significant once the behaviour and stress variables were included in the models. Household income decile was also not significantly associated with T2DM, once the behavioural and perceived life stress variables were added. Respondents absent from work or who did not have a job did not have significantly different likelihood of having T2DM when compared to those who worked at a job/business. None of the occupations were found to be significantly associated with T2DM when compared to those who were not working or missing.

In general, these results confirmed that both sex/gender and elements of SES (income, education, work, and family status) were associated with T2DM, although none of the SES variables, other than education, remained significant once the behavioural variables and stress were added to the models.

5.3 Models stratified by sex/gender

A model was estimated in which interactions of gender and several socioeconomic or sociodemographic variables were statistically significant (models not shown). In order to examine how sex/gender and SES might intersect to shape the risk of T2DM, we therefore stratified the analysis, producing separate models for males and females. Table 6 presents the results of the logistic regression model predicting T2DM by SES variables for males, and Table 7 presents the same model for females. SES, geographic, and demographic variables were included.

Table 6: Logistic regression models predicting Type 2 diabetes by socioeconomic status variables (males aged 18–75 years, 2015–16).

	OR (95% CI)		**OR (95% CI)**
Age		*Education*	
18 – 24	0.003* (<0.001-0.113)	Grade 13 and below	1.295* (1.039-1.614)
25 – 30	0.017* (0.008-0.035)	Secondary School †	1.000 (--)
31 – 35	0.088* (0.050-0.155)	Less than Bachelor's	0.913 (0.766-1.087)
36 – 40	0.159* (0.098-0.256)	Bachelor's Degree	0.717* (0.573-0.899)
41 – 45	0.303* (0.214-0.428)	Above Bachelor's	0.608* (0.443-0.835)
46 – 50	0.504* (0.370-0.688)	Not stated	0.898 (0.564-1.429)
51 – 55	0.623* (0.483-0.804)	*Economic Family Household*	
56 – 60†	1.000 (--)	Couple †	1.000 (--)
61 – 65	1.228 (0.993-1.519)	Child in a Couple Family	0.989 (0.819-1.196)
66 – 70	1.335* (1.058-1.686)	Lone Parent	0.866 (0.513-1.462)
71 – 75	1.563* (1.227-1.993)	Child in Lone Parent Family	1.378 (0.728-2.609)
Household income – Provincial deciles		Unattached Individual/other	0.835* (0.711-0.981)
Decile 1	1.323 (0.953-1.835)	*Cultural/Racial Background*	
Decile 2	1.071 (0.793-1.447)	Aboriginal	1.363* (1.016-1.829)
Decile 3	0.916 (0.673-1.245)	Black Only	3.144* (1.773-5.578)
Decile 4	1.072 (0.807-1.423)	East Asian	0.891 (0.544-1.461)
Decile 5†	1.000 (--)	Filipino Only	2.457* (1.036-5.829)
Decile 6	0.971 (0.728-1.295)	Latin America	0.810 (0.290-2.260)
Decile 7	0.886 (0.650-1.208)	Not stated	2.257 (0.643-7.920)
Decile 8	0.944 (0.710-1.257)	Other/multiple	1.478 (0.833-2.622)
Decile 9	0.765 (0.584-1.002)	South Asian	3.347* (2.320-4.830)
Decile 10	0.800 (0.601-1.066)	Southeast Asian	0.937 (0.290-3.028)
Working Status Last Week		West Asian/Arab only	2.507* (1.391-4.519)
Worked at a job/business †	1.000 (--)	White Only †	1.000 (--)
Absent from work	1.442* (1.047-1.986)		

Table 6, continued

	OR (95% CI)		**OR (95% CI)**
Did not have a job	1.215 (0.622-2.374)	*Urban/rural*	
Occupation		Urban †	1.000 (--)
Art, culture, recreation, sports	0.996 (0.373-2.655)	Rural Area	0.928 (0.808-1.066)
Business, finance, administration	1.100 (0.546-2.216)	*Province*	
Education, law, government	0.661 (0.314-1.395)	Alberta	0.868 (0.703-1.072)
Health	0.935 (0.402-2.175)	British Columbia	0.742* (0.599-0.920)
Management	0.768 (0.382-1.548)	Manitoba	0.778 (0.582-1.041)
Natural & applied sciences	0.513 (0.246-1.072)	New Brunswick	1.268 (0.947-1.698)
Natural resources, agriculture	0.740 (0.350-1.565)	Newfoundland and Labrador	1.006 (0.769-1.316)
Not working or missing †	1.000 (--)	Nova Scotia	1.444* (1.128-1.850)
Manufacturing and utilities	0.634 (0.297-1.352)	Ontario †	1.000 (--)
Sales and services	1.029 (0.520-2.039)	Prince Edward Island	0.989 (0.682-1.433)
Trades, transport operators	0.968 (0.486-1.930)	Quebec	0.832* (0.706-0.981)
		Saskatchewan	0.908 (0.693-1.188)
N	36898	-2 Log L	16462.330
DF	60	C statistic	0.774

Note: Data from the 2015–16 CCHS. Variance estimates calculated using bootstrapped weights.
† Reference category. * Values are significant at p<0.05

Table 7: Logistic regression models predicting Type 2 diabetes by socioeconomic status variables (females aged 18–75 years, 2015–16).

	OR (95% CI)		**OR (95% CI)**
Age		*Education*	
18 – 24	0.010* (0.002-0.062)	Grade 13 and below	1.361* (1.080-1.715)
25 – 30	0.078* (0.040-0.151)	Secondary School †	1.000 (--)
31 – 35	0.083* (0.049-0.140)	Less than Bachelor's	0.942 (0.775-1.144)
36 – 40	0.211* (0.129-0.344)	Bachelor's Degree	0.544* (0.405-0.732)
41 – 45	0.310* (0.201-0.478)	Above Bachelor's	0.460* (0.320-0.661)
46 – 50	0.537* (0.372-0.777)	Not stated	1.329 (0.661-2.674)
51 – 55	0.831 (0.622-1.110)	*Economic Family Household*	
56 – 60†	1.000 (--)	Couple †	1.000 (--)
61 – 65	1.185 (0.899-1.561)	Child in a Couple Family	0.956 (0.748-1.222)
66 – 70	1.450* (1.135-1.851)	Lone Parent	1.760* (1.102-2.811)
71 – 75	1.704* (1.297-2.239)	Child in Lone Parent Family	0.941 (0.620-1.427)
Household income – Provincial deciles		Unattached Individual/other	1.314* (1.100-1.571)
Decile 1	1.567* (1.133-2.166)	*Cultural/Racial Background*	
Decile 2	1.344 (0.988-1.828)	Aboriginal	1.574* (1.095-2.262)
Decile 3	1.161 (0.851-1.584)	Black Only	1.798 (0.860-3.759)
Decile 4	1.262 (0.918-1.735)	East Asian	1.194 (0.535-2.668)
Decile 5†	1.000 (--)	Filipino Only	2.460* (1.360-4.448)
Decile 6	1.250 (0.837-1.867)	Latin America	0.819 (0.266-2.517)
Decile 7	0.976 (0.697-1.366)	Not stated	1.858 (0.726-4.754)
Decile 8	0.710 (0.497-1.016)	Other/multiple	1.665* (1.078-2.570)
Decile 9	1.039 (0.741-1.457)	South Asian	3.342* (1.951-5.724)
Decile 10	0.602* (0.408-0.888)	Southeast Asian	0.914 (0.334-2.501)
Working Status Last Week		West Asian/Arab only	1.016 (0.527-1.955)
Worked at a job/business †	1.000 (--)	White Only †	1.000 (--)
Absent from work	1.178 (0.739 -1.877)		

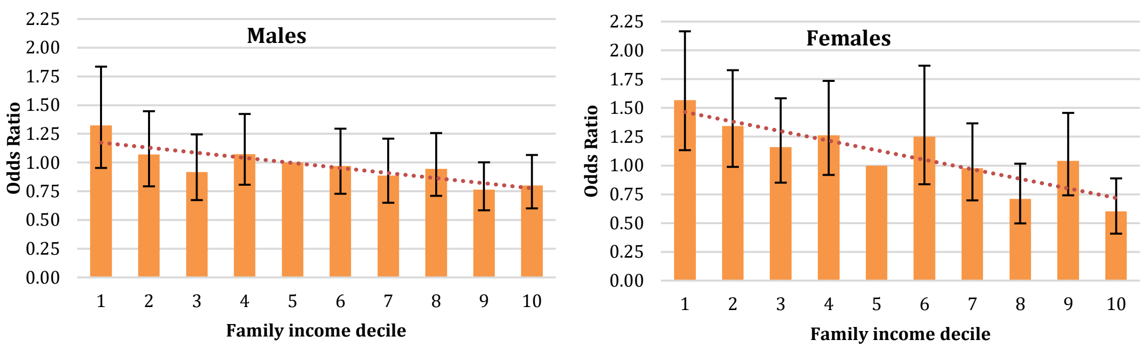
Table 7, continued

	OR (95% CI)		OR (95% CI)
Did not have a job	3.350* (1.305-8.599)	*Urban/rural*	
Occupation		Urban †	1.000 (--)
Art, culture, recreation, sports	1.962 (0.560-6.874)	Rural Area	0.913 (0.783-1.065)
Business, finance, administration	3.165* (1.215-8.249)	*Province*	
Education, law, government	3.325* (1.285-8.603)	Alberta	0.746* (0.578-0.964)
Health	3.835* (1.427-10.310)	British Columbia	0.719* (0.554-0.934)
Management	2.203 (0.756-6.421)	Manitoba	0.930 (0.677-1.280)
Natural & applied sciences	5.010* (1.558-16.116)	New Brunswick	1.008 (0.733-1.385)
Natural resources, agriculture	3.598 (0.163-79.590)	Newfoundland and Labrador	1.135 (0.841-1.533)
Not working or missing †	1.000 (--)	Nova Scotia	1.234 (0.915-1.665)
Manufacturing and utilities	2.561 (0.837-7.835)	Ontario †	1.000 (--)
Sales and services	2.459 (0.969-6.239)	Prince Edward Island	1.153 (0.760-1.747)
Trades, transport operators	3.262 (0.974-10.931)	Quebec	0.971 (0.795-1.186)
		Saskatchewan	1.206 (0.883-1.647)
N	40783	-2 Log L	12761.467
DF	60	C statistic	0.775

Note: Data from the 2015–16 CCHS. Variance estimates calculated using bootstrapped weights.
† Reference category. * Values are significant at p<0.05

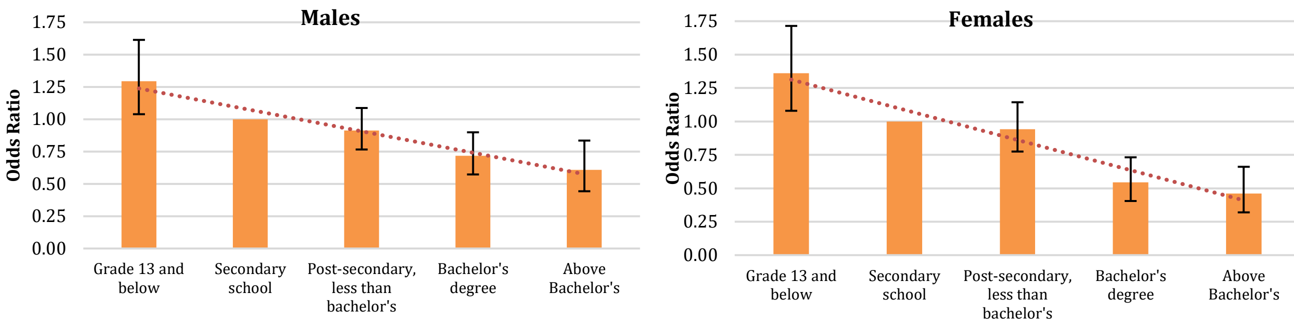
In the interaction models, the interaction of age and sex/gender was not significant. Accordingly, in the stratified models, the age dummies had a similar effect for males and females and reflected a generally linear relationship with T2DM risk. However, other variables did have different relationships to T2DM risk for men and for women.

Figure 2: Relative odds of T2DM by provincial family income decile, males and females



The provincial household income decile variable did interact significantly with sex/gender, and the model with the interaction fit the data significantly better than the model with only the main effects of those variables, according to a likelihood ratio test ($X^2 = 34.5$, *df=8)*. However, in the stratified models the provincial income variables were no longer significant, reflecting the reduced power in the split samples. Nonetheless, plotting the effects of the income dummies is instructive. In Figure 2, we present the effects of family income decile for males and females, independent of the other effects shown in Tables 5 and 6. We show these in two panels, rather than on the same axis, to reflect that the estimates resulted from separate models. For both the male and female samples, a decreasing linear relationship between income and risk is suggested. However, note that the slope implied for the female sample was steeper than for the male sample, which would reflect a stronger relationship between relative income level and diabetes risk, among women.

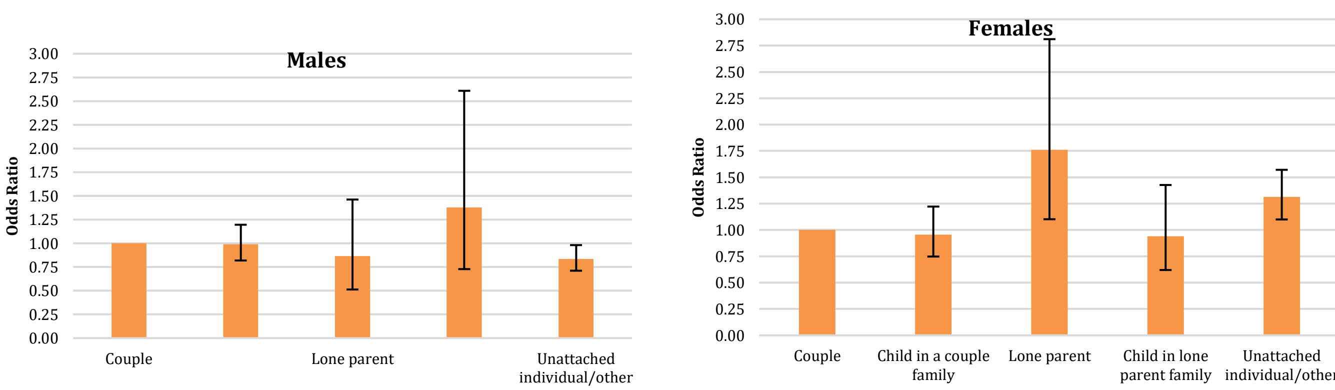
Figure 3: Relative odds of T2DM by educational attainment, Males and females



The effects of educational attainment also were not significantly different for men and women, judging by an insignificant interaction term (model not shown). In the stratified models, among both men (Table 6) and women (Table 7), those with less than high school (Grade 13 and below) had T2DM risk that was about a third higher than those with a secondary school diploma or certificate (Males: OR= 1.295, 95% CI=1.039–1.614, Females: OR= 1.361, 05%CI=1.080–1.715). Similarly, for both men and women, those with university degrees were protected against T2DM, compared with those with only secondary schooling. Although the interaction with sex/gender was not significant, Figure 3 presents the odds ratios and associated confidence intervals for the education attainment variables, from the models in Tables 6 and 7. As with income, comparing the odds ratios from the two models (Figure 3), it is suggestive that the relationship educational attainment and T2DM risk is stronger among women than among men, although the difference was not statistically significant in our sample.

Employment status and occupation also had different effects for men and for women. Among men, being absent from work in the previous week increased the risk for T2DM significantly, compared with those who had worked (OR=0.1.442, 95% CI=1.047–1.986), while the effect was not significant among women. However, conditional on having a job, there were clear difference in the effects of occupation type for men and for women. For men, none of the occupational categories included in Table 6 were significantly different from those not working, in terms of their diabetes risk, controlling for income, education, age, and the other variables in the model. However, among women, those in natural and applied sciences had the highest risk (OR=5.010, 95% CI=1.558–16.116), but women in business, finance and administration (OR=3.165, 95% CI=1.215–8.249), education, law and government (OR=3.325, 95% CI=1.285–8.603) and health (OR=3.835, 95% CI=1.427–10.310) also had significantly higher risk than those who were not working (Table 7).

Figure 4: Relative odds of T2DM by economic family status, Males and females



A clear difference between the models for men and women was found in the effects of economic family status, independent of the other effects in the models. As shown in Figure 4, men living as unattached individuals or in family forms not otherwise captured were at significantly lower risk to T2DM, compared with those living in a couple economic family (OR=0.835, 95% CI=0.711–0.981), while the other family status variables were not significant. Among women, those living as unattached individuals or in "other" families were at significantly *higher* risk than were women in couple families (OR=1.314, 95% CI=1.100–1.571). The most striking difference, though, was the very high risk of T2DM among female lone parents. Compared to women in couple families, female lone parents were more than 75% more likely to report having T2DM (OR=1.760, 95% CI=1.102–2.811), whereas lone male parents were not at significantly different risk than men in couple families.

There were both similarities and differences in the effects of cultural or racial background variables for men and for women. In both sex/gender models, people who reported being Aboriginal had much higher risk than those reporting "white only" ethnicity or race (Males: OR=1.363, 95% CI=1.016–1.829; Females: OR=1.574, 95% CI=1.095–2.262). Similarly, those reporting Filipino identity had almost equal odds for males and females, relative to the "white" reference group (Males: OR=2.457, 95% CI=1.036–5.829; Females: OR=2.460, 95% CI=1.095–4.448), as did those with South Asian backgrounds (Males: OR=3.347, 95% CI=2.320–4.830; Females: OR=3.342, 95% CI=1.951–5.724). However, there were also differences. In particular, among men, those with having West Asian or Arab backgrounds were at significantly higher risk than "white" men, controlling for the other variables in the model (OR=2.507, 95% CI=1.391–4.519). Among women, those reporting "other" or multiple backgrounds were at significantly higher risk (OR=1.665, 95% CI=1.075–2.570).

5.4 Addition of health behaviours to the stratified models

As a final step in modelling the risk for T2DM among men and women, we added the measures of health behaviour, and also stress, to the models for men and women. As in the models for both sex/genders combined, health behaviour variables included smoking, alcohol use, physical activity, and fruit and vegetable consumption. As described above, the stress variable was derived from the “perceived life stress” question in the CCHS, which asked respondents to report the amount of stress in their lives, on most days. We were interested in whether these appeared to have different effects in these models, controlling for the other SES, geographic and demographic variables (Tables 8 and 9). In general, these effects of the demographic and socioeconomic variables in these models were similar to those in the stratified models without the behavioural and perceived life stress variables.

Table 8: Logistic regression models predicting Type 2 diabetes by socioeconomic status and behavioural variables (Canadian males aged 18–75 years, 2015–16). (Model 8)

	OR (95% CI)		OR (95% CI)
Age		*Education*	
18 – 24	0.003* (<0.001-0.111)	Grade 13 and below	1.182 (0.946-1.477)
25 – 30	0.018* (0.009-0.037)	Secondary School †	1.000 (--)
31 – 35	0.092* (0.052-0.162)	Less than Bachelor's	0.938 (0.785-1.120)
36 – 40	0.159* (0.099-0.254)	Bachelor's Degree	0.772* (0.616-0.969)
41 – 45	0.305* (0.216-0.432)	Above Bachelor's	0.643* (0.465-0.889)
46 – 50	0.497* (0.366-0.676)	Not stated	0.906 (0.564-1.455)
51 – 55	0.626* (0.487-0.807)	*Economic Family Household*	
56 – 60†	1.000 (--)	Couple †	1.000 (--)
61 – 65	1.246* (1.007-1.543)	Child in a Couple Family	0.953 (0.789-1.151)
66 – 70	1.375* (1.089-1.737)	Lone Parent	0.802 (0.466-1.382)
71 – 75	1.555* (1.215-1.991)	Child in Lone Parent Family	1.403 (0.732-2.687)
Household income – Provincial deciles		Unattached Individual/other	0.826* (0.701-0.973)
Decile 1	1.175 (0.837-1.650)	*Cultural/Racial Background*	
Decile 2	0.966 (0.714-1.307)	Aboriginal	1.325 (0.985-1.782)
Decile 3	0.843 (0.618-1.149)	Black Only	2.577* (1.453-4.570)
Decile 4	1.035 (0.776-1.380)	East Asian	0.671 (0.405-1.112)
Decile 5†	1.000 (--)	Filipino Only	1.699 (0.715-4.034)
Decile 6	0.961 (0.716-1.289)	Latin America	0.773 (0.280-2.134)
Decile 7	0.929 (0.682-1.267)	Not stated	1.855 (0.544-6.324)
Decile 8	1.003 (0.749-1.343)	Other/multiple	1.309 (0.732-2.338)
Decile 9	0.827 (0.626-1.094)	South Asian	2.550* (1.768-3.678)
Decile 10	0.902 (0.675-1.205)	Southeast Asian	0.706 (0.217-2.297)
Working Status Last Week		West Asian/Arab only	1.965* (1.079-3.579)
Worked at a job/business †	1.000 (--)	White Only †	1.000 (--)
Absent from work	1.383* (1.001-1.910)		

Table 8, continued

	OR (95% CI)		OR (95% CI)
Did not have a job	1.252 (0.653-2.403)	*Urban/rural*	
Occupation		Urban †	1.000 (--)
Art, culture, recreation, sports	1.128 (0.428-2.973)	Rural Area	0.901 (0.781-1.039)
Business, finance, administration	1.081 (0.547-2.134)	*Province*	
Education, law, government	0.670 (0.325-1.380)	Alberta	0.834 (0.673-1.033)
Health	0.899 (0.397-2.034)	British Columbia	0.772* (0.622-0.958)
Management	0.780 (0.396-1.534)	Manitoba	0.771 (0.576-1.032)
Natural & applied sciences	0.488 (0.237-1.001)	New Brunswick	1.085 (0.801-1.471)
Natural resources, agriculture	0.758 (0.363-1.584)	Newfoundland and Labrador	0.920 (0.699-1.211)
Not working or missing †	1.000 (--)	Nova Scotia	1.280 (0.993-1.649)
Manufacturing and utilities	0.623 (0.298-1.304)	Ontario †	1.000 (--)
Sales and services	1.013 (0.521-1.969)	Prince Edward Island	0.914 (0.627-1.332)
Trades, transport operators	0.979 (0.503-1.907)	Quebec	0.866 (0.731-1.026)
Type of Smoker		Saskatchewan	0.865 (0.654-1.145)
Daily	0.798* (0.657-0.969)	*Physical Activity Indicator*	
Not at all †	1.000 (--)	No physical activity minutes	1.520* (1.306-1.769)
Occasionally	0.921 (0.631-1.346)	Physically active at/above †	1.000 (--)
Drank Alcohol - Frequency		Physically active below	1.109 (0.940-1.308)
2 to 3 times a month	0.838 (0.656-1.069)	*Fruit/Vegetable Daily Consumption*	
2 to 3 times a week	0.531* (0.431-0.654)	Low consumption	1.021 (0.892-1.167)
4 to 6 times a week	0.341* (0.263-0.442)	Medium consumption †	1.000 (--)
Every day	0.350* (0.277-0.441)	High consumption	0.700 (0.422-1.159)
Less than once a month	1.241 (0.999-1.542)		
Once a month	0.895 (0.681-1.176)		
Once a week	0.665* (0.529-0.835)		
Never †	1.000 (--)		

Table 8, continued

	OR (95% CI)		OR (95% CI)
Life Stress			
A bit stressful †	1.000 (--)		
Not at all stressful	0.863 (0.702-1.060)		
Not very stressful	0.745* (0.630-0.880)		
Quite a bit stressful and extremely stressful	1.037 (0.861-1.248)		
N	36898	-2 Log L	15980.842
DF	76	C statistic	0.793

Note: Data from the 2015–16 CCHS. Variance estimates calculated using bootstrapped weights.
*† Reference category. * Values are significant at p<0.05*

Table 9: Logistic regression models predicting Type 2 diabetes by socioeconomic status and behavioural variables (Canadian females aged 18–75 years, 2015–16). (Model 9)

	OR (95% CI)		**OR (95% CI)**
Age		*Education*	
18 – 24	0.012* (0.002-0.075)	Grade 13 and below	1.219 (0.954-1.558)
25 – 30	0.089* (0.045-0.176)	Secondary School †	1.000 (--)
31 – 35	0.087* (0.051-0.150)	Less than Bachelor's	0.986 (0.811-1.200)
36 – 40	0.218* (0.133-0.357)	Bachelor's Degree	0.619* (0.455-0.842)
41 – 45	0.305* (0.197-0.472)	Above Bachelor's	0.532* (0.368-0.768)
46 – 50	0.556* (0.382-0.808)	Not stated	1.332 (0.643-2.756)
51 – 55	0.855* (0.636-1.150)	*Economic Family Household*	
56 – 60†	1.000 (--)	Couple †	1.000 (--)
61 – 65	1.196 (0.899-1.592)	Child in a Couple Family	0.885 (0.690-1.135)
66 – 70	1.436* (1.111-1.856)	Lone Parent	1.511 (0.926-2.466)
71 – 75	1.608* (1.206-2.144)	Child in Lone Parent Family	0.889 (0.583-1.355)
Household income – Provincial deciles		Unattached Individual/other	1.275* (1.057-1.538)
Decile 1	1.341 (0.969-1.857)	*Cultural/Racial Background*	
Decile 2	1.204 (0.882-1.642)	Aboriginal	1.546* (1.077-2.220)
Decile 3	1.081 (0.788-1.484)	Black Only	1.459 (0.682-3.121)
Decile 4	1.231 (0.887-1.707)	East Asian	0.919 (0.393-2.151)
Decile 5†	1.000 (--)	Filipino Only	1.850* (1.025-3.338)
Decile 6	1.305 (0.866 -1.968)	Latin America	0.698 (0.227-2.144)
Decile 7	1.068 (0.760-1.501)	Not stated	1.609 (0.600-4.315)
Decile 8	0.765 (0.531-1.103)	Other/multiple	1.307 (0.843-2.027)
Decile 9	1.161 (0.821-1.643)	South Asian	2.464* (1.399-4.337)
Decile 10	0.729 (0.489-1.088)	Southeast Asian	0.721 (0.267-1.945)
Working Status Last Week		West Asian/Arab only	0.771 (0.403-1.478)
Worked at a job/business †	1.000 (--)	White Only †	1.000 (--)
Absent from work	1.112 (0.693-1.784)		

Table 9, continued

	OR (95% CI)		OR (95% CI)
Did not have a job	3.431* (1.356-8.681)	*Urban/rural*	
Occupation		Urban †	1.000 (--)
Art, culture, recreation, sports	2.219 (0.643-7.656)	Rural Area	0.881 (0.753-1.032)
Business, finance, administration	3.240* (1.260-8.327)	*Province*	
Education, law, government	3.368* (1.324-8.567)	Alberta	0.742* (0.574-0.961)
Health	3.653* (1.361-9.807)	British Columbia	0.783 (0.602-1.018)
Management	2.244 (0.776-6.492)	Manitoba	0.919 (0.665-1.270)
Natural & applied sciences	4.987* (1.579-15.754)	New Brunswick	0.873 (0.634-1.203)
Natural resources, agriculture	3.533 (0.162-76.847)	Newfoundland and Labrador	1.007 (0.742-1.367)
Not working or missing †	1.000 (--)	Nova Scotia	1.145 (0.848-1.546)
Manufacturing and utilities	2.479 (0.822-7.472)	Ontario †	1.000 (--)
Sales and services	2.446 (0.981-6.099)	Prince Edward Island	1.100 (0.717-1.688)
Trades, transport operators	2.962 (0.858-10.226)	Quebec	1.052 (0.851-1.301)
Type of Smoker		Saskatchewan	1.125 (0.822-1.539)
Daily	1.141 (0.851-1.531)	*Physical Activity Indicator*	
Not at all †	1.000 (--)	No physical activity minutes	1.637* (1.336-2.007)
Occasionally	0.725 (0.471-1.118)	Physically active at/above †	1.000 (--)
Drank Alcohol - Frequency		Physically active below	1.165 (0.973-1.395)
2 to 3 times a month	0.634* (0.455-0.883)	*Fruit/Vegetable Daily Consumption*	
2 to 3 times a week	0.344* (0.260-0.454)	Low consumption	0.952 (0.791-1.145)
4 to 6 times a week	0.384* (0.211-0.698)	Medium consumption †	1.000 (--)
Every day	0.317* (0.125-0.804)	High consumption	0.712 (0.476-1.066)
Less than once a month	1.021 (0.839-1.243)		
Once a month	0.759* (0.580-0.993)		
Once a week	0.467* (0.346-0.631)		
Never†	1.000 (--)		

Table 9, continued

	OR (95% CI)		OR (95% CI)
Life Stress			
A bit stressful †	1.000 (--)		
Not at all stressful	0.835 (0.663-1.052)		
Not very stressful	0.791* (0.651-0.961)		
Quite a bit stressful and extremely stressful	1.113 (0.904-1.369)		
N	40783	-2 Log L	12386.580
DF	76	C statistic	0.801

Note: Data from the 2015–16 CCHS. Variance estimates calculated using bootstrapped weights.
*† Reference category. * Values are significant at p<0.05*

6.0 Discussion

6.1 Key findings:

The analyses presented above, using data from the 2015/2016 Canadian Community Health Survey were presented in order to address three research questions. This study aimed to determine whether the two dimensions of social identity-sex/gender and socioeconomic position, interact to structure the risk of T2DM as well as determine whether there is evidence of these differences in risk of diabetes for men and women, and to study the observable processes that might be leading to (or "amplifying") observed differences in diabetes risk. The relationship between T2DM and sex/gender was thought to be associated with social identity, such as socioeconomic position, and behavioural factors. We also examined evidence of the role of family context in producing these differences by studying the risk of diabetes by family and household configuration, independent of household income or socio-economic position (Figure 1). Additionally, we focused on the observable processes that potentially lead to (or "amplify") observed differences in diabetes risk.

The present findings show that sex and gender differences in the relationships between socioeconomic position and T2DM may be explained in part by differences in health-related behaviours (physical activity, fruit and vegetable consumption, smoking, alcohol consumption, preventive health care use) and stress. The differences in the relationships between socioeconomic position and T2DM associations for men and women may also be because of differences in health-related behaviours or measures of stress. We believe that the socioeconomic and behavioural factors affect men and women differently. The current findings from the multivariable regression models and that are presented in the figures show that when controlling for socioeconomic position, age, household configuration, and social identity, diabetes risk remains significantly associated with gender/sex. Therefore, this indicates that demographic, social identity (age, race, sex/gender), geographic, socioeconomic, behavioural, and stress factors might have an independent association with T2DM risk and that there may be an amplifying effect on T2DM risk amongst the processes.

6.2 Income:

Results from our multivariable logistic regression models showed that household income provincial decile was significantly associated with outcomes of T2DM in Table 4 (males and females), when controlling for age, sex, cultural/racial background, education, economic family household, occupation, working status last week, and urban/rural ($p<0.05$). However, when health behaviours/stress variables including type of smoker, drank alcohol – frequency, physical activity indicator, fruit/vegetable consumption, stress, were added to the model (Table 5, males and females), household income provincial decile was no longer significant. Although, the model for males only (Table 6), which controlled for demographic identity, geography, and social determinants and not behaviour/stress variables, showed that household income was not significantly associated with T2DM risk, income was related to risk for T2DM in the female-only model (Table 7). Household income was not significant for males (Table 8) or females (Table 9), once behavioural/stress variables were included. These results might be explained partly by physical inactivity in women being more likely. Physical inactivity can uniformly predict significant differences in T2DM risk for men and women (McCarthy, Davey, Wackers, & Chyun, 2014). Women with diabetes are more likely to be less physically active than men with diabetes (De Melo et al., 2013). Being physically active on a constant basis is fundamental for an individual's management of T2DM (McCollum, Hansen, Lu, & Sullivan, 2005). As my study uses cross-sectional data, these actual processes cannot be fully understood. However, a national

Australian cross-sectional study studied the association of biomarkers of diabetes and cardiovascular disease and socioeconomic position (education and household income) in males and females and found that women with diabetes have a lower likelihood of having higher household incomes, even with equivalent education and occupation statuses, than men with diabetes (Kavanagh et al., 2010). Kavanagh et al. (2010) indicate that males and females variably expend their income on material resources. As such, higher household income of individuals may influence an individual's health behaviours and stress levels. This may also explain why there is an independent association of household income and T2DM, despite attenuation of the association between household income and T2DM risk when behaviours/stress variables are present in the model.

6.3 Education:

Results from our multivariable logistic regression models showed that those with lower levels of education (Grade 13 and below) were at consistently higher risk for diabetes, while those with a Bachelor's degree and above were at lower risk of T2DM. This was true when controlling for age, sex, cultural/racial background, education, economic family household, occupation, working status last week, and urban/rural. With the addition of health behaviours/stress variables in Table 5 (males and females), these effects of education remained significant. These education effects were also significant in the models for males only (Table 6) and females only (Table 7), which both controlled for demographic identity, geography, and social determinants and removed behaviour/stress variables. When health behaviours and stress were added into the models, both males (Table 8) and females (Table 9) with a Bachelor's degree were at significantly lower risk for T2DM. Our finding is that higher educational attainment is visibly associated with decreased risk of T2DM.

Similarly, Choi et al.'s (2011) cross-sectional study investigated the association amongst self-reported educational attainment and chronic diseases, including diabetes, with logistic regression models that controlled for demographics, accessibility to care, health behaviours and comorbidities, and found that the prevalence of chronic diseases, including T2DM, is reduced. Therefore, educational attainment can be used to predict health effects and how chronic conditions will be managed (Hwang & Shon, 2014). The degree of education is an indication of the potential a person has to apply the information learned and create healthy behaviours, such that one can efficiently regulate or decrease the risk of chronic conditions (Geyer, Hemström, Peter & Vågerö, 2006). Higher education is greatly related with an improved social and physical environment (Hwang & Shon, 2014). Low educational attainment has been associated with reduced social support and greater vulnerability to physical and environmental exposures (Silles, 2009). Also, the slight difference in odds ratios for women and men education levels and T2DM risk could be explained by educational attainment being seen as predictor of SES (Tang et al., 2003). For example, education attests to the individual's knowledge of health problems, their inclination to solicit health information, and adopt beneficial health behaviours (Tang et al., 2003). Women may be more likely to adopt healthy behaviours than men, because their education level is indicative of their SES (Tang et al., 2003). Women and men may have varying outlooks on wellbeing, health behaviours, and lifestyles that may be attributed to this difference in significant odds ratios for all models. However, more research is required to determine what these differences in odds ratios for men and women's educational attainment and risk of T2DM is a result of. Overall, a strong cross-sectional association between educational attainment and risk of T2DM for men and women was apparent in our findings.

6.4 Economic Family Household:

Our multivariable logistic regression models showed evidence of significant differences in diabetes risk by household type. However, with the addition of health behaviours/stress variables in Table 5 (males and females), these effects of economic family household were no longer significant. The model for males only (Table 6) was significant for unattached individual/other and indicated lower risk for diabetes and the model for females only (Table 7) were significant for lone parent and unattached individual/other and indicated that risk for diabetes was higher; both models controlled for demographic identity, geography, and social determinants and removed behaviour/stress variables. When health behaviours and stress were added into the models, results were significant for both but risk was lower for males who were unattached individual/other males (Table 8) and was higher females who were unattached individual/other (Table 9). Our findings indicate that women in lone parent and unattached individual/other households are associated higher risk for T2DM, while men in unattached individual/other are associated with decreased risk of T2DM.

Women who are lone parents and unattached individual/other are associated with higher risk for T2DM because of their economic family household status. A previous study determined that women who lived alone were at an increased risk for developing type 2 diabetes (Lidfeldt, Nerbrand, Samsioe, & Agardh, 2005). Health outcomes of diabetes can be impacted by the individual's household status and corresponding living conditions (Lidfeldt et al., 2005). The psychosocial stressors from everyday life may explain this impact (Lidfeldt et al., 2005). A woman without a partner is more likely to be burdened socioeconomically, due to women working more often in low salary jobs (Lidfeldt et al., 2005). The stress resulting from working and reduced consistency has been associated with T2DM for lone parent and unattached/other women. This finding may explain why lone parent and unattached individual/other women have a higher association than men for T2DM risk.

Men who were unattached individual/other are associated with lower risk for T2DM. However, our study is not consistent with literature because several studies indicate that men living alone in economic family household configuration are actually at higher risk for T2DM. For example, a Korean cohort study found that men living alone are at greater risk for T2DM than household with multiple members (Nam et al., 2021). Living alone can affect health outcomes, like T2DM, and lifestyle variables (Nam et al., 2021). The principal mechanism for this association between living and T2DM is not understood, but living alone is associated with economic, social, lifestyle and environmental factors and these factors can impact an individual's dietary behaviour (Wham et al., 2015; Kucukerdonmez, Navruz Varli, & Koksal, 2017). People who live alone are more at risk for depression because they are typically lower income than those who are not living alone (Chou, Ho, & Chi, 2006). Therefore, our findings suggest the opposite of literature for men in unattached individual/other economic family household configuration.

6.5 Cultural/Racial Background:

For cultural/racial background, our multivariable logistic regression models found that Aboriginal, Black Only, Filipino Only, Other/multiple, South Asian and West Asian/Arab only are associated with a greater risk for diabetes than White Only, when controlling for age, sex, cultural/racial background, education, occupation, working status last week, and urban/rural. Specifically, when health behaviours/stress variables were included in Table 5 (males and females), Aboriginal, Black Only, Filipino Only, South Asian were significant. The model for males only (Table 6) was significant for Aboriginal, Black Only, Filipino Only, South Asian and West Asian/Arab only and indicated higher risk for diabetes and the model for females only

(Table 7) was significant for Aboriginal, Filipino Only, Other/multiple, and South Asian and indicated that risk for diabetes was higher, while both models were controlling for demographic identity, geography, and social determinants and removed behaviour/stress variables. When health behaviours and stress were added into the models, Black Only, South Asian, and West Asian/Arab Only were significant for males (Table 8) and Aboriginal, Filipino Only, and South Asian for females (Table 9), with associated risk T2DM being greater for both. Our findings indicate that women and men in Aboriginal, Black Only, Filipino Only, Other/multiple, South Asian and West Asian/Arab are associated with increased risk of T2DM.

Studies have identified that racial/ethnic groups have differences in risk because of various factors including genetic differences, early-life risk factors, and diet. There are several genetic differences across racial/cultural groups and they are likely to partially account for the varied diabetes prevalence among racial groups (Golden, Yajnik, Phatak, Hanson, & Knowler, 2019). However, evaluating environmental sociocultural variables of ancestral groups is challenging to do due to ambiguousness, which, in turn, means that environmental factors confound genetic ancestry associations (Golden et al., 2019). Also, some studies have found that early-life determinants contribute to T2DM prevalence among racial/ethnic groups such as the "thrifty phenotype" hypothesis and the life course trajectory, which demonstrates the risk of "double burden" of malnutrition on the T2DM risk over a lifetime for rural versus urban environments (Golden et al., 2019). The thrifty phenotype hypothesis proposes that the susceptibility to T2DM occurs due to altered survival in an environment of poor nutrition during early life, mainly during the first 1,000 days (during foetal and infancy growth), via epigenetic programming (Hales & Barker, 1992; Golden et al., 2019). Variations in diet between racial or ethnic groups potentially play a large part in affecting intergenerational susceptibility to T2DM

(Golden et al., 2019). For instance, South Asian diets can include macronutrient imbalances and are characteristically rich in carbohydrates and energy and have a higher glycemic index (Burden, Samanta, Spalding & Burden, 1994). The variances in diet among racial/ethnic groups therefore influence diabetes risk. All of these factors potentially play a role in the higher risk of T2DM for racial/ethnic groups.

6.6 Occupation and Working Status Last week:

The multivariable logistic regression models for occupation and working status did suggest that the type of work was associated with diabetes risk. Again, health behaviours and stress variables were added (Table 5, males and females), no associations of occupational category and diabetes risk were significant. In the model for males only (Table 6), occupation was not significant but women who were absent from work had a higher risk for T2DM (Table 7). When health behaviours and stress were added into the models, only being absent from work was associated with higher T2DM risk for males (Table 8), while women working in business, finance, administration, education, law, government, health, natural and applied sciences, as well as those were not working (Table 9) were at higher T2DM risk.

Literature indicates that diabetes risk is linked to socioeconomic position. Socioeconomic position includes occupation and working status. Low SES is associated with a high risk of T2DM. There are key differences in T2DM risk for people who are low SES due to their occupations or being unemployed (Carlsson, Andersson, Talbäck & Feychting, 2019). The employees that are high risk may have a greater prevalence of obesity, smoking, and limited physical activity. Specific occupations may contribute to diabetes such as those that are shift work, that include extended sitting for hours, or cause psychological stress (Biswas et al., 2015; Nyberg et al., 2014; Pan, Schernhammer, Sun, & Hu, 2011). A Swedish nationwide cohort study specifically observed an association between occupation and T2DM that showed large variances in the prevalence of lifestyle risk factors (Carlsson et al., 2019). Carlsson et al. (2019) noted that individuals in occupations that were at high-risk had a greater likelihood of being overweight, smoking and being less physically active compared to individuals who were working in low-risk occupations and this was most likely to lead to a high prevalence and incidence of T2DM (Carlsson et al., 2019). To highlight, some work like transport occupations involve fluctuating work hours, extended periods of sitting for hours, and being stressful, while manufacturing jobs may involve less sitting than white-collar jobs, but could be higher stress and consist of shift work, whereas individuals working in computing based careers or as engineers are more prone to being less physically active at work (Carlsson et al., 2019). Men and women's risk was different in these occupations, with more men affected than women by T2DM. Lifestyle risk factors associated with specific types of work and occupations can therefore affect an individual's risk of developing the disease. Consequently, the working status and occupation that an individual works in influences their health outcome and can contribute to their T2DM risk.

6.7 Health Behaviours and Perceived Life Stress:

The multivariable logistic regression models that included health behaviours (the type of smoker, drank alcohol –frequency, physical activity indicator, and fruit/vegetable daily consumption) and stress showed us some of what we predicted, that poor diet, physical inactivity, and more stress are associated with a higher T2DM risk. Our study found that smoking (Table 8) and drank alcohol – frequency (Tables 5, 8 and 9) for drinking 2 to 3 times a month, 2 to 3 times a week, 4 to 6 times a week, once a week, and every day were both protective, when controlling for age, sex, cultural/racial background, education, occupation, working status last week, and urban/rural. No physical activity minutes was associated with a higher risk for T2DM for males (Table 8) and females (Table 9). Perceived life stress for not at all stressful (Table 5) and not very stressful was associated with a lower T2DM risk (Tables 5, 8, and 9). Differences in odds ratio were found when health behaviours and stress variables were added into the model, which might indicate some mediation effects in the association between sex and gender, SES, and T2DM risk, but we are unable to definitively conclude this because the data that was analyzed is cross-sectional. However, from this study, we can learn that health behaviours and perceived life stress have independent associations with T2DM risk for both males and females. Independently studying T2DM risk with regard to SES, sex and gender, health behaviours and perceived life stress simplifies the actual phenomenon through which individuals who have poorer health behaviours and greater perceived life stress might have a higher likelihood of developing T2DM.

6.8 Policy Implications:

There are several policy implications that arise from the results of this study. For this discussion, policies will not be centred on individual behaviours, such as health literacy, but rather on structural factors like socioeconomic status (SES) because the results of the study are predominantly focused on how structural factors such as income and SES shape T2DM development. Policies that affect the general wellbeing of people will be highlighted and consequently, SES and income and their relation to T2DM risk are at the forefront of these policy implications.

Policies that affect the structural factors associated with T2DM risk and an individual's position in society, rather than individual behaviours are important to address because they directly take on the actual determinants of T2DM risk. Some policies that could be introduced are universal basic income, subsidized housing, and adequate income protection for individuals who are dependent on hazardous and low salary work (Diabetes Canada, 2020). Guaranteeing universal basic income for all would ensure that individuals have access to a minimum income, allowing them to meet their fundamental needs (Diabetes Canada, 2020). Universal basic income presents the opportunity for all to afford the basic resources needed to obtain healthier health outcomes (Diabetes Canada, 2020). Also, subsidized housing can help reduce the financial burden that comes from renting and housing (Diabetes Canada, 2020). By subsidizing housing, there may be more funds available for people to make healthier dietary choices (Diabetes Canada, 2020). Income protection is also pertinent to reducing the financial burden associated with certain jobs and low salaries. These policies seek to address the structural issues that shape T2DM risk. By accounting for these policies, there is potential to reduce the risk of T2DM development upstream by financial means and social position.

7.0 Limitations and Strengths

There are some limitations of this study. The data from the CCHS 2015 and CCHS 2016 are self-reported by participants. This indicates that the variables that are self-reported such as whether the participants have diabetes, their age at diagnosis/incidence, diet intake, food consumption patterns, health behavioural factors, BMI, physical activity level, and smoking status may be misreported (due to social desirability or by an overestimation or underestimation), ultimately, presenting an information bias into the study. Additionally, the CCHS data are cross-sectional in nature and measures prevalent cases of diabetes, instead of incident cases, meaning that the data will continually demonstrate participants' survival factors. Finally, it may be challenging to establish a temporal relationship and whether the outcome of having T2DM occurred following exposure to the factors being studied, because the survey data are cross-sectional and not longitudinally collected.

Another significant limitation is that the coding of certain variables in the CCHS 2015/16 such as the cultural and racial background was coded incorrectly by Statistics Canada. Specifically, there was a problem with the respondents being incorrectly assigned to the category of "other/multiple racial or cultural origins" that could not be corrected. However, this affected few cases and is not likely to have affected our results.

There are strengths to this study despite these limitations. The sample size for this study is large and nationwide (provinces only). Most importantly, this study examined the structure of T2DM risk between social identity-sex/gender and socioeconomic position with the CCHS 2015/16 cross sectional data, which adds a Canadian study to the literature in this field.

8.0 Conclusion and Future Research

In conclusion, our findings suggest that the two dimensions of social identity-sex/gender and socioeconomic position may interact to structure the risk of T2DM and that there are differences in risk of diabetes for men and women. The observable processes that might be leading to and amplifying observed differences in diabetes risk are factors such as age, sex, cultural/racial background, education, income, economic family household, occupation, working status last week, and health behaviours/stress variables. Results of this study suggest that the relationship between T2DM and sex/gender is associated with social identity, such as socioeconomic position, and some health behavioural factors and perceived life stress.

Future studies should focus on the underlying mechanisms influencing socioeconomic and behavioural/stress variables on sex and gender and T2DM risk, which would be invaluable to the efforts made thus far in T2DM prevention amongst men and women. The complex dimensions that structure the risk of T2DM between sex and gender and T2DM risk, including the variables of social identity and health behaviours/stress, should be studied with longitudinal data in order to obtain incidence of T2DM. Understanding this structure will provide new direction for research that can directly address the different fundamental causes at play in the development of T2DM for men and women. Overall, the findings of this study recommend that prevention strategies for diabetes should include approaches that incorporate both healthy individual behaviours and public policy that recognize the influential role that SES and sex and gender have on the variations observed in the prevalence and incidence of T2DM for males and females.

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10.0 Appendix

Appendix

Correction steps for Education variables, EHG2DVR9 and EHG2DVR3:

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* Respondent 9 levels - highest level of education - correction steps for
EHG2DVR9;
if EHG2_01 = 1 and
(EHG2_03 = 2 or EHG2_04 = 1) then EHG2DVR9 = 1; else
if EHG2_01 = 2 and
(EHG2_03 = 2 or EHG2_04 = 1) then EHG2DVR9 = 2; else
If EHG2_01 = 3 and EHG2_02 = 2 and
(EHG2_03 = 2 or EHG2_04 = 1) then EHG2DVR9 = 3; else
if (EHG2_02 = 1 and EHG2_03 = 2) or
EHG2_04 = 2 then EHG2DVR9 = 4; else
if EHG2_04 = 3 then EHG2DVR9 = 5; else
if EHG2_04 = 4 then EHG2DVR9 = 6; else
if EHG2_04 = 5 then EHG2DVR9 = 7; else
if EHG2_04 = 6 then EHG2DVR9 = 8; else
if EHG2_04 = 7 then EHG2DVR9 = 9; else
if (EHG2_01 IN (7, 8, 9) and EHG2_02 = 2) or
EHG2_02 IN (7, 8, 9) or
EHG2_03 IN (7, 8, 9) or
EHG2_04 IN (97, 98, 99) then EHG2DVR9 = 99;

* Respondent 3 levels - highest level of education - correction steps for
EHG2DVR3;
if (EHG2_01 in (1,2) or EHG2_02 = 2) and
(EHG2_03 = 2 or EHG2_04 = 1) then EHG2DVR3 = 1; else
if (EHG2_02 = 1 and EHG2_03 = 2) or
EHG2_04 = 2 then EHG2DVR3 = 2; else
if EHG2_04 IN (3, 4, 5, 6, 7) then EHG2DVR3 = 3; else
if (EHG2_01 IN (7, 8, 9) and EHG2_02 = 2) or
EHG2_02 IN (7, 8, 9) or
EHG2_03 IN (7, 8, 9) or
EHG2_04 IN (97, 98, 99) then EHG2DVR3 = 9;
```