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Proportion of Canadian Adults with Unreported Type 2 Diabetes who Experience a Related Hospitalization: Results from Canadian Community Health Survey and Discharge Abstract Database Linkage

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Abstract

Background: People with type 2 diabetes (T2D) may go undiagnosed and subsequently be hospitalized with T2D.

Objective: Determine the percentage of Canadians, with unreported T2D, who experience a T2D hospitalization

Methods: Using linked dataset, respondents who reported no diabetes in the Canadian Community Health Survey, were followed in the Discharge Abstract Database for T2D hospitalization event.

Results: 0.56% of men and 0.44% of women, who reported no diabetes, were hospitalized with T2D. Older Age, higher BMI and worse self-reported health increased T2D hospitalization in both men and women. In women, drinking alcohol, smoking tobacco and lower physical activity were associated with an increase in T2D hospitalization.

Conclusion: Significant proportion of Canadians experience a T2D hospitalization when self-reporting undiagnosed diabetes. Potential risk factors were identified; however, further research needs to focus on understanding these relationships.

Keywords

Undiagnosed diabetes, type 2 diabetes, preventable hospitalizations, diabetes in Canada, linked dataset, Canadian Community Health Survey

Summary for Lay Audience

Type 2 diabetes (T2D) is a growing public health concern and early detection and management is key to controlling the pandemic. Since T2D can be present for a long time before patients start experiencing symptoms, some Canadians may be unaware of having the condition. These individuals may eventually present to the hospital with related complications.

The objective of this thesis was to determine what percentage of Canadians who reported not having T2D, might actually have the disease and end up in the hospital with related condition. This thesis assessed whether the percentage of Canadians who reported no diabetes but were hospitalized with T2D related condition changed over time. Lastly, this thesis looked at potential factors that might increase or decrease T2D hospitalization risk among this group.

This thesis utilized a national self-reported survey (Canadian Community Health Survey [CCHS]) and national hospitalization records (Discharge Abstract Database [DAD]). Canadians who responded to the CCHS and reported no previous T2D diagnosis were followed in the DAD to see if they experienced a related hospitalization.

This thesis found that 0.56% of men and 0.44% of women were hospitalized with T2D even though they reported no diabetes. This percentage increased with each year for men between 2000 to 2009 from 0.41% to 0.71%. With increasing age, higher BMI and self-reported poor health, Canadians were more likely to be hospitalized with T2D. In Canadian women, alcohol drinking prevented T2D hospitalization, while smoking tobacco, and lower physical activity were associated with increase in T2D hospitalization.

Identifying T2D early could be an effective strategy to minimize the long-term impacts of the disease. Future research should focus on linking other administrative datasets, such as physician billing or laboratory results to get a full picture of this problem.

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Chapter 1

1 Diabetes in Canada

This chapter will provide background information to contextualize the study rationale by introducing diabetes, discussing the health and economic consequences of diabetes and defining undiagnosed diabetes and its health consequences. Lastly, this chapter will identify the study objectives.

1.1 Types of diabetes

Diabetes is a chronic disease that occurs either when the pancreas does not produce enough insulin or when the body does not respond appropriately to insulin (a hormone that is released by the pancreas to regulate blood sugar).[1] Although many types of diabetes have been described, there are three main types: type 1, type 2 and gestational diabetes.[2] Type 1 diabetes, an autoimmune disease, is characterized by decreased insulin production. It requires daily administration of insulin for management.[2] Type 2 diabetes (T2D), results from the ineffective use or production of insulin.[2] Gestational diabetes is characterized by hyperglycemia during pregnancy and typically disappears following childbirth.[2] Other types of diabetes are uncommon and include those associated with genetic defects, surgeries, and specific medications that affect the body's ability to produce or respond to insulin.[2]

1.2 Diabetes prevalence and incidence

The prevalence of diabetes is growing in Canada and in other parts of the world, especially T2D. In 2014, there were 422 million adults worldwide living with diagnosed diabetes, compared to 108 million in 1980 (rising from 4.7% to 8.5%).[3] In Canada, 8.1% of the population was living with diagnosed diabetes between 2013 and 2014; an increase of 37% from 2003 to 2004.[4] By 2025, the prevalence of diagnosed diabetes is estimated to reach 12.1% (5 million people).[5] More than 90% of people with diagnosed diabetes have T2D,[4] which is the focus of this thesis.

Although a consistent rise in prevalence of T2D has been observed, the incidence of T2D increased until 2006–2007, from 6.7 to 7.6 per 1,000 population, but then decreased to 6.3 per 1,000 population by 2013–2014.[4] This may be because Canadians with T2D now live longer due to advancements in treatment of patients diagnosed with T2D.[6] The number of Canadians living with T2D is also expected to increase in the coming years due to the aging population.[4]

1.3 Health consequences of type 2 diabetes

With long-term T2D, there are risks of complications, typically categorized as macrovascular (due to damage to larger blood vessels) and microvascular complications (due to damage to small blood vessels).[7] Macrovascular complications include cardiovascular diseases (CVD) such as heart attacks, strokes and insufficiency in blood flow to legs.[7] Microvascular complications include retinopathy, nephropathy and neuropathy.[7]

Cardiovascular disease is an umbrella term for all types of diseases that affect the heart or blood vessels.[7] This includes coronary heart disease, which can cause heart attacks, stroke, and peripheral artery disease.[7] People with T2D are two to four times more likely to have CVD compared to people without T2D; CVD accounts for a large proportion of the excess mortality related to T2D.[8–10] T2D has been associated with earlier development of CVD; men and women with T2D tend to be about 15 years younger than those without T2D in the same CVD risk category.[10]

Diabetic retinopathy, typically occurs in individuals who have had T2D for several years.[7] It is caused by small blood vessel damage to the back layer of the eye.[7] Diabetic retinopathy is a leading cause of blindness and visual disability.[7] Up to 21% of patients with T2D have retinopathy at the time of diagnosis, and most develop some degree of retinopathy over time.[11] The prevalence of diabetic retinopathy has been shown to vary from 28.8% in persons who had T2D for less than five years to 77.8% in persons who had T2D for 15 or more years.[12]

Nephropathy is also caused by damage to small blood vessels in the kidneys.[7] This can cause kidney failure, and lead to death.[7] In developed countries, diabetic nephropathy is a leading cause of dialysis and kidney transplant.[7] Approximately, 30 to 50% of individuals with T2D have nephropathy; the prevalence of nephropathy ranges between 25% in younger T2D patients (<65 years old) to nearly 50% in older T2D patients (≥65 years old).[13]

Lastly, neuropathy, the most common complication of T2D, is nerve damage caused by hyperglycemia and decreased blood flow to small blood vessels.[7] This nerve damage can lead to sensory loss, gastrointestinal side effects, impotence in diabetic men.[7] Overall, two thirds of T2D patients have objective evidence for some variety of neuropathy, but only about 20% have symptoms.[14] The prevalence of neuropathy has been shown to be 22% in youth with T2D.[15]

1.4 Economic consequences of type 2 diabetes

T2D has a number of economic consequences including medical costs, lost productivity, premature mortality, and intangible costs in the form of reduced quality of life.[16] The global economic burden of T2D was estimated to be $1.3 trillion USD in 2015 which accounts for 1.8% of the world's GDP.[16] Indirect costs, such as reduced productivity, work absences and inability to work due to T2D related disability, accounted for 35% of the total burden. Relative to GDP, T2D has a significant impact on North America as well as in middle-income countries.[16] The absolute costs are expected to increase to $2.1 trillion USD by 2030. This translates to an increase in costs as a share of global GDP from 1.8% in 2015 to a 2.2% in 2030.[17]

The economic burden of T2D in Canada is estimated to increase from $6.3 billion annually in 2000 to $16.9 billion by 2020.[18] T2D associated costs accounted for $3.5% of public health care spending in Canada with direct costs representing about 17% of the total cost.[18] Diabetes Canada has projected the overall direct cost of T2D to be $3.1 billion in 2020.[18]

These health care costs of T2D arise due to the need for acute inpatient hospitalizations, physician visits, prescription medications and assistive devices.[19] Inpatient hospitalization accounted for nearly 50% of attributable costs in incident T2D cases.[19] Between 2011/2012 and 2021/2022, 2.16 million new cases of T2D are estimated to result in $15.36 billion in Canadian health care costs, almost two-thirds of which will be spent on acute hospitalizations and physician services.[20]

1.5 Undiagnosed type 2 diabetes

The onset of T2D is characterized by a gradual increase in fasting and post-prandial (i.e. after meals) blood sugar. It can take 9-12 years before glycemic levels are sufficiently high to lead to symptoms and a diagnosis of T2D.[21] Consequently, individuals who have T2D can spend a significant period of time unaware that they have the disease.[2] This is referred to as undiagnosed T2D; and is typically defined as those whose T2D has not been diagnosed by a physician but whose plasma glucose levels satisfy established criteria for T2D.[22] During this period, patients may not receive the treatment that they need for diabetes, which may result in development of complications before diabetes diagnosis.[2] These complications can include heart disease, stroke, kidney failure, nerve damage, blindness, erectile dysfunction and amputation; complications which can impose enormous strains on the health care system.[23]

As such, the Diabetes Canada 2018 clinical practice guidelines recommend that all individuals be evaluated annually for T2D risk based on their demographic and clinical profile. The guidelines recommend that people aged 40 years and over be screened every three years for T2D or more frequently (every 6 to 12 months) for those at very high risk.[24] The hope is to capture T2D early in its progression and prevent the development of T2D related complications. Despite these practice guidelines, the Public Health Agency of Canada reported that the prevalence of total T2D may be underestimated by 30% as a result of undiagnosed T2D.[25]

1.5.1 Health consequences of undiagnosed type 2 diabetes

The health outcomes are worse for individuals living with undiagnosed T2D compared with individuals who have been previously diagnosed.[26–28] In hospitalized patients,

undiagnosed T2D patients, compared to known T2D patients, had an increased risk of morbidity, mortality, extended hospital length of stay and more adverse outcomes following discharge.[26] Patients with previously undiagnosed T2D were 28% more likely to experience death within 30 days from myocardial infarction compared to patients without T2D.[27] Among those who have undergone coronary bypass operations, 5.2% had undiagnosed T2D and faced a higher mortality rate than those with diagnosed T2D.[28]

Similar data exist in Canada, where those with T2D diagnosed at a later stage were more likely to be hospitalized and had a longer length of hospital stay compared with those with an early diagnoses.[29] Cardiovascular disease had a greater impact on females with T2D than males, especially when diagnosed at a later stage.[29] Females who were diagnosed with T2D late had three to four times increased risk of CVD mortality and CVD hospitalizations compared with their male counterparts who were diagnosed late.[29]

All-cause mortality risk has shown to be similar in subjects with diagnosed and undiagnosed T2D, despite undiagnosed T2D patients having a lower cardiovascular risk profile than those with diagnosed T2D.[30] A Canadian study reported that despite the patient charts indicating dysglycemia among patients admitted to the hospital for coronary heart disease, glucose monitoring occurred less than 30% of the time.[31]

1.6 Preventable hospitalizations and type 2 diabetes

T2D is a chronic condition that can be managed in a primary care setting. As such it is considered to be an ambulatory care-sensitive condition (ACSC) as hospitalization for this condition might be preventable.[32–34] There is evidence to suggest that a regular source of primary care and maintaining glucose levels can result in fewer T2D hospitalizations.[35,36] When individuals have access to primary care, are cared for effectively, have screening in a timely manner and are supported in managing a chronic condition like T2D, patients face a lower risk of acute complications and hospitalizations[36,37]. Those with undiagnosed diabetes might face more complications requiring presentation to hospital.[37]

Between 2001 to 2005, an estimated 4.2 million Canadians aged 12 to 74 experienced at least one preventable hospitalization; T2D related hospitalizations represented 30% of these hospitalizations.[38] Studies conducted in single emergency departments in the United States estimated that approximately 9% of patients who presented to the emergency department for acute illness had previously undiagnosed T2D.[39–41] In Europe, 9.5% of those presenting to hospital had previously undiagnosed T2D.[42] Those with undiagnosed T2D were admitted to hospital predominantly for cardiac disorders, nervous system disorders such as cerebral infarction, and infections/infestations.[42] In Canada, there is little understanding of the proportion of patients with undiagnosed T2D who present to hospital, along with a lack of data on trends in T2D related preventable hospitalizations among undiagnosed T2D patients.

Overall, a decrease in T2D related preventable hospitalizations has been documented in Canadian studies, which may suggest a sustained improvement in T2D care, despite the increase in the T2D prevalence.[43,44] In Alberta and British Columbia, declining T2D related preventable hospitalization was observed between 1998 and 2009.[43] Whereas in Ontario, between 1994 and 1999, hospital admissions for hyperglycemic emergencies decreased by 33%.[44] However, these studies investigated the temporal trends among individuals with previously diagnosed diabetes.

1.7 Rationale and objectives

Diagnosing T2D at an early stage is key to preventing complications, avoiding hospitalizations, and reducing health care costs.[45] It has been shown that the intensity of glucose, blood pressure and cholesterol treatment after diagnosis is less important than the time of treatment initiation.[45] Therefore, early detection of T2D is of utmost importance as screening strategies can decrease the incidence of myocardial infarction, decrease T2D related microvascular complications, and increase the number of Quality Adjusted Life Years (QALY).[46]

Currently, no Canadian literature exists on the proportion of individuals with undiagnosed diabetes who present to the hospital with T2D. Furthermore, no Canadian

literature has examined national trends in T2D related hospitalizations among patients with undiagnosed T2D.

Lastly, it is important to study the factors associated with undiagnosed T2D requiring hospitalization and whether these determinants differ for males and females. There is literature that explores sociodemographic, health-related and behavioural factors associated with T2D hospitalization. However, these studies have not examined these factors in the context of undiagnosed T2D patients. Therefore, the objectives of this thesis are as follows:

Objective 1: Identify the percentage of men and women in Canada with undiagnosed T2D who experience T2D related hospitalizations.

Objective 2: Explore temporal trends of T2D related hospitalizations among Canadian men and women with undiagnosed T2D.

Objective 3: Explore the role of sociodemographic, health-related, and behavioural factors associated with T2D related hospitalizations among Canadian men and women with undiagnosed T2D.

Chapter 2

2 Literature Review

This chapter will lay out the etiology of T2D and its potential risk factors. This chapter will explain how T2D is diagnosed, which will lay a foundation to further discuss the prevalence, temporal trends and risk factors for undiagnosed T2D. Furthermore, this chapter will review the prevalence of T2D hospitalizations as well temporal trends and risk factors of T2D hospitalization. Literature looking at undiagnosed diabetes in hospital setting will be summarized. Lastly, this chapter will summarize the in-depth literature review, restate the objectives of this study and present hypotheses.

2.1 Glucose regulation in type 2 diabetes

In order to ensure normal body function, the human body maintains a tight control of its blood glucose levels.[47] This is accomplished by a highly complex network of various hormones and neuropeptides released mainly from the brain, pancreas, liver, intestine as well as adipose and muscle tissue.[47] The pancreas plays a key role by secreting the blood sugar-lowering hormone insulin and glucagon.[47] When blood glucose levels are low, the pancreas secretes glucagon, which increases blood glucose levels through glycogenolysis (conversion of glycogen into glucose).[47] When blood glucose levels are high, insulin is released to trigger glucose uptake into insulin-dependent muscle and adipose tissues as well as to promote glycogenesis (conversion of glucose into glycogen).[47]

Disturbances in the interplay of the hormones and peptides involved may lead to metabolic disorders such as T2D.[48] T2D usually begins with insulin resistance, a condition in which muscle, liver, and fat cells do not use insulin well.[48] As a result, the body needs more insulin to help glucose enter cells. At first, the pancreas produces more insulin to keep up with the added demand.[48] This is referred to as the prediabetes stage. In the prediabetes stage the blood sugar levels might not be high enough to be considered T2D, however, long-term complications such as microvascular and macrovascular

disorders may manifest in some people.[49] Over time, the pancreas cannot produce enough insulin and blood glucose continue to rise[48]

Although T2D may remain asymptomatic for many years, some of the symptoms as a result of hyperglycemia include increased thirst, increased hunger, dry mouth, frequent urination, unexplained weight loss, fatigue, blurred vision, headaches and rarely loss of consciousness.[3]

2.2 Type 2 diabetes risk factors

Numerous risk factors have been investigated and linked to T2D. Overweight and obesity are the most significant risk factors. Adults with a body mass index (BMI) of 40 or higher are 7.37 times more likely to be diagnosed with T2D.[50] For people with obesity, T2D is associated with poor control of blood sugar, blood pressure and cholesterol levels and many of the health complications of T2D become more severe when they are compounded by overweight or obesity.[50–52]

Other factors such as age, sex, marital status, education, socioeconomic status (SES) and ethnicity have also been linked to T2D. For instance, the prevalence and incidence of diagnosed T2D has been shown to increase with age and is higher among males (8.7% and 6.5 per 1,000 population) than among females (7.6% and 5.3 per 1,000 population).[4] A systematic review and meta-analysis of six observational studies conducted in different parts of the world found that marital status also increased the risk of T2D by 26% when there was a spousal history of T2D.[53] Furthermore, a recent systematic review and meta-analysis of 23 observational studies from different parts of the world concluded that compared with a higher educational level and income, lower educational levels and income were associated with an increased risk of T2D.[54] Social determinants of health not only increase the risk of developing T2D but can also have an impact on health outcomes, such as glycemic control, low density lipoproteins and blood pressure for a person with T2D.[55,56] Additionally, ethnicity has been linked with T2D. For example, a study in the United States found that compared with white participants, Black and Asian participants were twice as likely to have T2D.[57] The incidence of T2D has been shown to be highest among South Asians, particularly 20 to 29-year-olds, with

rates 2.2 times that of white individuals and 3.1 times that of Chinese individuals.[58] Lastly, multiple studies have shown higher rates of T2D among Indigenous people in Canada compared to non-Indigenous Canadians while controlling for other sociodemographic characteristics.[2,59,60]

Although it does not have a clear pattern of inheritance[61] at least 38 T2D associated genes have been identified, however, only about 10% of the heritability of T2D can be explained by these genes.[61–63] Many affected individuals have at least one close family member, such as a parent or sibling, with the disease.[64] The increased risk is likely due to shared genetic factors and lifestyle influences that are shared by members of a family.[63]

Modifiable health behaviours such as unhealthy diet, smoking tobacco, alcohol drinking and physical inactivity have also been associated with T2D. A systematic review and meta-analysis of 25 cohort studies found that active smoking is positively associated with an increased risk of T2D.[65] The association between the number of cigarettes smoked and T2D risk was consistent with a dose-response phenomenon.[65] Moderate alcohol drinking, relative to abstainers (current non-drinkers and never drinkers), played a protective role against T2D according to a systematic review of 38 observational studies.[66] However, reductions in risk appeared to be specific to women, who exhibit a decreased risk of T2D with moderate alcohol consumption.[66] Other health behaviours such as increasing the amount of green leafy vegetables in an individual’s diet has been shown to help reduce the risk of T2D.[67,68] Habitual consumption of sugar sweetened beverages has been shown to be associated with a greater incidence of T2D, independently of adiposity.[69] Furthermore, meat consumption has shown to increase risk of T2D.[70] Lastly, there is strong evidence for an inverse association between physical activity and risk of T2D, which may partly be mediated by reduced adiposity.[71]

2.3 Onset of type 2 diabetes

A highly cited study by Harris et al. estimated the onset of T2D to be 9 to 12 years before its clinical diagnosis.[21] This was based upon the prevalence of retinopathy at time of

diagnosis of T2D. The authors estimated that 20.8% of patients with diagnosed T2D in United States and 9.9% of patients in Australia had retinopathy at time of T2D diagnosis.[21] Under the assumption that retinopathy increased linearly with longer duration of T2D, they extrapolated that the onset of detectable retinopathy occurred 4 to 7 years before diabetes diagnosis.[21] Because research has indicated that T2D may be present for 5 years before retinopathy becomes evident, authors concluded that in some cases, the onset of T2D may occur 9 to 12 years before its clinical diagnosis.[21]

A more recent study aimed to extrapolate the mean duration of undiagnosed T2D from the proportion of subjects with observable retinopathy at diagnosis of T2D.[72] They performed eyes examination and ascertained date of first diagnosis of T2D.[72] Of the 295 patients examined, 14.68% had some form of retinopathy at time of diagnosis. The findings suggested that detectable retinopathy occurred 5.8 years before actual diagnosis.[72] The fact that a period of dysglycaemia is likely to predate development of retinal changes, this study implied that the duration of undiagnosed T2D is longer, about 10 years.[72]

Even still, there was debate as to whether the relation between retinopathy and duration of T2D is a linear one.[73] Porta et al. further argued the plausibility of such a long duration of undiagnosed T2D in countries with regulated health care systems in which blood glucose concentrations are ideally measured more often than every 10 years due to T2D guidelines.[73] Using Akaike Information Criterion and coefficient of determination to choose the best-fitting model, the authors concluded that T2D may be present 4 to 6 years before clinical diagnosis.[73]

2.4 Diagnosis of type 2 diabetes

The following tests can be used in clinical setting to diagnose T2D: fasting blood glucose (FPG) test, glycated hemoglobin (A1C) test, oral glucose tolerance (OGT) test and random glucose test (RGT).[74] An FPG test is typically taken after an overnight fast and [74] T2D is diagnosed with a FPG level of 126 mg/dL (7 mmol/L) or higher on two separate tests.[74] A1C is a blood test which measures blood sugar attached to hemoglobin, and represents blood sugars over 2-3 months.[74] The higher the blood

sugar levels, the more hemoglobin have sugar attached.[74] An A1C level of 6.5 percent or higher on two separate tests indicates a T2D diagnosis.[74] An OGT test requires individuals to fast overnight.[74] A sugary liquid is consumed the day of the test and blood sugar levels are tested periodically for the next two hours.[74] A reading of more than 200 mg/dL (11.1 mmol/L) after two hours indicates T2D.[74] Lastly, a RGT can be administered anytime to measure blood glucose levels and a reading of more than 200 mg/dL (11.1 mmol/L) may suggest diabetes.[74]

The diagnostic criteria for T2D are based on thresholds of glycemia that are associated with microvascular disease, especially retinopathy.[74] To confirm T2D cases, a plasma glucose in the T2D range should be confirmed with a secondary test in asymptomatic individuals.[74] This is because hyperglycemia detected under acute event or other stress may be transitory.[75] This does not in itself confirm a diagnosis of T2D.[75] If two tests are above the T2D threshold, then a diagnosis of T2D is confirmed.[74,75] Table 2.1 from Diabetes Canada guidelines summarizes T2D diagnostic tests criteria.[74]

Table 2.1: Type 2 diabetes diagnosis criteria

Test	Normal Range
FPG	≥ 7.0 mmol/L
A1C	≥ 6.5%
OGT	≥ 11.1 mmol/L
RGT	≥ 11.1 mmol/L

2.5 Undiagnosed type 2 diabetes

Globally, nearly half of all T2D cases are considered undiagnosed.[76] However, the prevalence of undiagnosed T2D shows geographic variation. Undiagnosed T2D has been reported to be as low as 10% of total T2D (0.9% of population) in higher income countries such as Ireland,[77] and as high as 55% of total T2D (3.96% of population) in low income countries such as rural Bangladesh.[78]

A Canadian study assessed the prevalence of undiagnosed T2D in patients over the age of 40 who visited their family physicians for routine care.[79] Patients were asked to fill out a questionnaire indicating whether they had been previously diagnosed with T2D. Those

who indicated no previous diagnosis were tested for T2D.[79] They found previously undiagnosed T2D in 2.2% of patients after screening in the primary care setting.[79] A higher percentage of men (2.4%) than women (2.0%) had previously undiagnosed T2D.[79] However, the authors noted that these prevalence estimates maybe biased since the study population may not have been entirely representative of the Canadian population over 40 years of age.[79] For instance, the study sample had a T2D prevalence of 16.4%, which is much higher than the rate of T2D in the general Canadian population.[79]

A more recent Canadian study conducted in 2005 using Canadian Health Measure Survey (CHMS) data aimed to estimate the prevalence of undiagnosed T2D in Canada.[80] CHMS collected self-reported health data through household interviews.[80] Additionally, the CHMS collected direct physical measures such as biospecimens using mobile examination centers.[80] This study found that 1.13% (~20% of total T2D) of the Canadian adult population had undiagnosed T2D based on FPG levels; whereas 3.09% (~40% of total T2D) of the Canadian adult population was classified as undiagnosed T2D using A1C level as a criterion.[80] Undiagnosed T2D was defined as not self-reporting T2D and having a blood glucose level that met the diagnostic criteria.[80] The proportion of undiagnosed T2D prevalence was higher for males compared with females (22% vs. 18% of total T2D, respectively) under the FPG criterion, whereas under the A1C criterion, the proportion of undiagnosed T2D prevalence was lower for males compared with females (37% vs. 46% of total T2D, respectively).[80] Studies have shown that the A1C test has a low sensitivity and high specificity for identifying T2D, which varied as a function of age and race.[81,82] This is to say that while the A1C test at the 6.5% diagnostic threshold may be good at ruling out T2D, it may wrongly classify non-diabetic individuals as having T2D. Furthermore, the study used data which excluded Canadians living on reserves or on Crown lands, people residing within institutions, those from certain remote geographical regions, and full-time members of the Canadian Forces.[80] Therefore, these estimates might also be biased in estimating the true prevalence of undiagnosed T2D.[80]

2.5.1 Temporal trends in undiagnosed type 2 diabetes

There is evidence to suggest that undiagnosed T2D as a proportion of total T2D has significantly declined since the 1970s to early 2000s due to rigorous screening for those at higher risk.[83] Undiagnosed T2D as proportion of total T2D declined from 40% in 1988 to 31% in 2012 in the United States (US) according to one study.[57] This was true across age, sex, race, educational level and income groups except for younger participants (age 20-44, 40.4% in 1988 to 40.4% in 2012).[57] Similarly, in the US, the incidence of T2D increased sharply during 1990 and 2008, before leveling off with no significant change during 2008 and 2012.[84] The incidence per 1,000 persons was 3.2 in 1990, 8.8 in 2008, and 7.1 in 2012.[84]

Certainly there has been a sharp decline in undiagnosed T2D as a proportion of total T2D; however, in the US, temporal trends in the crude prevalence of undiagnosed T2D remained stable over time.[85–87] Rates of undiagnosed T2D fluctuated between 3.1% to 3.9% of total population during the period of 1988 and 2012. Even though more T2D cases were detected, the crude prevalence of undiagnosed T2D did not change. This may be due to an increase in new cases of T2D. Obesity is on the rise, putting people at higher risk for developing T2D, especially in young adults.[88,89] The leveling off of T2D incidence rates in 2012 might not necessarily suggest a decrease in T2D cases. Younger adults who may have T2D might go unnoticed and hence would explain the unchanged crude prevalence of undiagnosed T2D despite higher detection rates.

The temporal trends studies mentioned above used survey data that used single FPG, OGT or AlC tests measurements to determine undiagnosed T2D in the US. Such single measurements may not provide a confirmatory T2D diagnosis. A more recent study in the US re-examined the crude prevalence of confirmed undiagnosed T2D. Confirmed undiagnosed T2D was defined as both elevated levels of fasting glucose and A1C (fasting glucose ≥7.0 mmol/L and A1C ≥6.5%) in persons without diagnosed T2D.[90] They estimated undiagnosed T2D crude prevalence increased during the past two decades (from 0.89% in 1988 to 1994 to 1.2% in 2011 to 2014) but has decreased over time as a proportion of total T2D cases.[90] This is much lower than the prevalence provided in the

studies above. Additionally, this study also suggested an increase in crude prevalence of undiagnosed T2D whereas the previous studies noted a stabilization of undiagnosed T2D.

Other high-income countries with similar health care systems, such as Germany, have also seen a decline in the prevalence of undiagnosed T2D as proportion of total T2D (3.8% to 2.0% between 1997-2011).[91] However, the crude undiagnosed T2D prevalence has remained stable.[91] Although there is literature on the estimated prevalence of undiagnosed T2D in Canada,[80] thus far, no literature exists on trends over time in the prevalence of undiagnosed T2D. With increasing rates of obesity observed in Canada,[92,93] incidence of new T2D might also increase leading to no change observed in the crude prevalence of T2D despite the increase in detection rate.

2.5.2 Undiagnosed type 2 diabetes risk factors

Both ethnicity and obesity have been linked not only with diagnosed T2D, but also with undiagnosed T2D. Members of some minority groups not only have elevated risk of developing T2D but are also more likely to go undiagnosed; especially in Asian, Hispanics and black participants in some studies.[94–97] For example, undiagnosed T2D crude prevalence was two times higher in non-Hispanic blacks and Mexican Americans than in non-Hispanic whites.[86] Obesity, a risk factor for undiagnosed T2D, is also higher among racial minority groups.[98,99] Another study results found undiagnosed T2D was more common in overweight or obese adults, older adults and racial/ethnic minorities (including Asian Americans).[90]

Some sociodemographic characteristics such as income, education, sex and rurality are also risk factors for undiagnosed T2D. Individuals with less than a high school education were twice as likely to have undiagnosed T2D compared to individuals with higher education level.[100] Individuals in lower income quintiles were also twice as likely to have undiagnosed T2D compared to individuals in middle income groups.[100] At the national level, undiagnosed T2D prevalence was higher among men (5.0%) than among women (3.2%).[101] Furthermore, a Canadian study found higher rates of undiagnosed T2D in rural patients compared to urban patients (2.0% vs 2.9%, respectively).[79]

There is also evidence to suggest that receiving health care in the past year and routine patterns of primary health care utilization were associated with undiagnosed T2D.[102,103] People with undiagnosed T2D were more likely than those with diagnosed T2D to report not having made any health care visits in the past year (39.2% versus 13.4%, respectively) and not having a place to go for primary health care (16.6% versus 3.7%, respectively).[102] A Canadian study examined risk factors for undiagnosed T2D and classified patients diagnosed with T2D as 'early' or 'late' depending on when T2D related comorbidities or complications had developed at the time of diagnosis.[104] This study found that patients with a late T2D diagnosis were less likely to report having a regular medical doctor.

Factors such as smoking tobacco, alcohol drinking, physical activity and fruit and vegetable consumption have been studied and associated with undiagnosed T2D. Both smoking and drinking were shown to be risk factors for undiagnosed diabetes.[105] Current smokers compared to those who have never smoked had 1.47 higher odds of undiagnosed diabetes.[105] Daily drinking also put individuals at 1.64 higher odds of having undiagnosed diabetes.[105] In contrast, a Chinese study found current smoking to be a protective factor against undiagnosed diabetes.[106] Another study conducted in United Kingdom investigated the association between fruits and vegetable consumption in subjects aged 40 to 64 years.[107] Participants underwent an OGT test, and their fruit and vegetable consumption was assessed.[107] Frequency of average yearly vegetable consumption was inversely associated with the risk of having undiagnosed T2D (Odds Ratio [OR]= 0.18) and the effect remained significant after adjusting for age, sex and family history; however the effect diminished after adjusting for BMI.[107] Individuals who reported frequent average yearly fruit consumption were less likely to have undiagnosed T2D than were those who reported infrequent consumption, but this relationship was not significant (OR = 0.52). [107] In contrast, another study found that increase in vegetable consumption was a protective factors against undiagnosed diabetes but only in women (OR = 0.56).[108] Additionally, 70% of undiagnosed T2D individuals reported physical inactivity, which was much higher than those with diagnosed T2D (56%) and non-T2D individuals (50%).[109]

2.6 Preventable hospitalizations

As defined by the Canadian Institute of Health Information (CIHI), ACSC includes epilepsy, chronic obstructive pulmonary disease, asthma, heart failure and pulmonary edema, hypertension, angina and diabetes.[110] Hospitalization due to those condition are considered potentially preventable; rates of preventable hospitalization has been used an indicator of the quality and performance of primary care system.[110] T2D related hospitalization are considered potentially preventable, as uncontrolled T2D can result in complications that can require extensive care, including hospitalization.[111,112].

In 2011, preventable hospitalizations comprised approximately 6% of all hospitalizations.[38] Among those with a preventable hospitalization, 20% were hospitalized for T2D.[38] In European countries with a similar health care system as Canada, T2D hospitalization ranged from 4% to 14% of total preventable hospitalizations.[113] In the Canadian context, a study from western provinces found that the rate of yearly hospitalization among patients diagnosed with T2D was 1.1% in Alberta and 0.8% in British Columbia.[43] In Ontario, 31.8% of T2D patients had at least one emergency department visit and 13.7% had a hospitalization due to T2D related hospitalization.[114]

2.6.1 Temporal trends in type 2 diabetes related hospitalizations

Overall, a decrease in T2D related hospitalizations has been documented in studies, which may suggest a sustained improvement in T2D care, despite the increase in the T2D prevalence.[33,43,115] Overall, preventable hospitalization rates in Canada have decreased by 22% between 2001-2002 and 2006-2007, after population growth and aging were taken into account.[33] This decline is greater than the 14% drop observed for all medical hospitalizations over the same period.[33] In 1998, the adjusted preventable hospitalization rate for T2D among diagnosed T2D patients was 2.9% in Alberta and 1.7% in British Columbia, compared to 1.1% and 0.8% in 2009, respectively.[43] Overall, the number of people with T2D more than doubled in both provinces between 1998 and 2009.[43] The number of hospitalizations also increased but at a much slower pace, translating into decreasing rates of hospitalization over the study period.[43]

Between 1994 and 1999, hospital admissions for hyperglycemic emergencies in Ontario decreased by 33%. There was also a marked decline in hospital admissions for hypoglycemia and an associated decrease in emergency department visits for T2D.[44]

Studies examining trends of T2D related preventable hospitalization among patients diagnosed diabetes have shown a declining trend in the US as well.[43,116,117] In the US, T2D related preventable hospitalization (including uncontrolled T2D, short and long term complications and lower extremity amputations) declined 27% from 1988 to 2008.[116] This was true for all ages except for those between 18 and 44 who showed no significant change in the rates of T2D related hospitalization.[116] During the period of 2005 to 2014, the annual count of T2D hospitalizations increased from 500,444 to 577,040. However, no changes were observed in the rate of T2D related hospitalization among individuals with T2D.[117] Subgroup analysis revealed a significant increase in T2D related hospitalizations due to acute complications in the age-group 18–44 years.[117] The slight increase in hospitalization rates due to T2D short-term complications balanced by a slight decrease in hospitalization rates due to uncontrolled T2D led to no observable change in hospitalization rates during 2005 to 2015 in the US.[117]

2.6.2 Preventable hospitalization and undiagnosed diabetes

Preventable hospitalization definitions pertains to hospitalizations experienced by individuals diagnosed with ACSC. However, for the purpose of this thesis, the definition was extended to include individuals who reported undiagnosed diabetes. If individuals were diagnosed in a timely manner, they might have not developed conditions requiring hospitalizations. Therefore, these hospitalization could have been prevented as well.

2.6.3 Risk factors of type 2 diabetes related hospitalization

Several sociodemographic risk factors such as sex, education, marital status and income have been associated with increased rates of T2D related hospitalization. Hospitalized individuals with T2D were shown to have lower educational status, lower household income, and were unmarried compared with T2D patients in the never hospitalized group.[118] For T2D, the hospitalization rate for men was about 16% higher than for

women.[33] Socioeconomic effects of higher education, as well as individual income, were important factors that affected disparities in T2D related hospitalization.[119] An inverse gradient between income level and T2D related hospitalizations was observed. Individuals with T2D in the lowest income quintile were 44% more likely to be hospitalized compared to those in the highest quintile (16.4% versus 11.4%).[120] The relationship between income and T2D related hospitalizations persisted after adjusting for age, sex, comorbidity, frequency of physician visits, continuity of care, physician specialty and geographic region.[120] Socioeconomic advantage increased the hospitalization rate in both men and women alike.[121]

The proportion of patients hospitalized for T2D related complications increased with age.[118] Furthermore, there is evidence to suggest the adjusted odds of hospitalization for both males and females follows a parabolic path.[122] The relationship is such that, among adults with T2D, the odds of hospitalization decreased with age until 60 years old and then increased with advancing age.[122] Furthermore, a Canadian study examined the hospitalization rate for individuals with T2D and found higher hospitalization rates among those who were older; around 34% of participants with T2D were aged 65 or older when hospitalized, compared with 12% of those aged 14 to 44.[123]

An individuals' BMI can also influence T2D related hospitalization with studies suggesting that both underweight and overweight, compared to normal weight, can increase hospitalization risk. For example, more than half (52%) of the patients with T2D related complications had a BMI lower than 24.[118] A Canadian study found that, men (OR=1.24) and women (OR=1.25) who were overweight were at an increased risk for general hospitalization compared to their counterparts with a normal weight.[124] Participants with obesity had a higher risk of hospitalization: Hazard Ratio (HR)=1.82 for those aged 25 to 44 years, HR=1.29 for those aged 45 to 64 years, and HR=1.46 for those 65 years and older.[125]

A study from Alberta, Canada found First Nations adults had almost four times the odds of having a potentially preventable hospitalization or emergency department visit for T2D compared to non-First Nations adults.[122] The rate of preventable hospitalizations

among urban Métis adults was found to be twice that of non-Indigenous adults.[126] Even when demographic, geographic and socioeconomic characteristics were taken into account, Métis had 1.5 higher odds of preventable hospitalization, overall.[126] Most commonly, these hospitalizations were for T2D or chronic obstructive pulmonary disease.[126] Among persons aged 35 years or older, Indigenous men were twice as likely to be hospitalized for T2D related illness compared to their non-Indigenous counterparts.[127]

Another Canadian study found, after accounting for differences in service use, that individuals living in rural areas of Ontario Canada were up to 1.8 times more likely to visit an emergency department or be admitted to a hospital for management of T2D than those living in urban communities.[44] Furthermore, those residing in remote areas of the province were nearly three times as likely to suffer from preventable hospitalizations.[44] More remote, northern areas had higher rates of admission for hypoglycemia and emergency department visits for T2D throughout the period of study but experienced comparable, or even greater declines in rates, as areas in southern Ontario.[44]

A study from the Canadian province of Alberta found that limited or increased use of primary care among diabetic patients was associated with increased risk of a subsequent hospitalization.[128] Compared to patients with 1 to 4 primary care visits, patients with no visits to a primary care physician and those with 5 to 9 visits were 11% and 6% more likely to experience a subsequent hospitalization, respectively.[128] This study concluded that those who visited primary care too much or too little were more likely to have a hospitalizations.[128] This may be because those with worse health use primary care services more frequently. Additionally, not using primary care service can lead to worsening of T2D related complications. In contrast, another Canadian study concluded that primary care use may not be a significant predictor of subsequent hospitalization among individuals with T2D; those who consulted with a family doctor in the past 12 months had equal hospitalization rates (24%) to those who did not consult a family doctor in the past 12 months (24%).[123]

Modifiable health behaviours such as smoking, drinking alcohol, physical activity and diet have also been associated with T2D hospitalization events. An Australian study found an increased risk of hospital admissions in smokers and physically inactive patients.[129] Those who never smoked were less likely than former or current smokers to be hospitalized (19%, 27% and 25%, respectively).[123] In contrast, regular alcohol drinkers had lower hospitalization rates than those who drank occasionally or were non-drinkers.[123] Lastly, increased fruit and vegetable consumption has been associated with a decrease in BMI and subsequent hospitalization.[130]

2.7 Undiagnosed type 2 diabetes detected in hospital

Several studies have been conducted to estimate the prevalence of T2D in a hospital setting among previously undiagnosed T2D patients. In the US, a prospective cohort study aimed to estimate the percentage of T2D cases in a hospital setting among previously undiagnosed patients. Of the 508 patients admitted to the hospital emergency department, 50 (9.8%) patients had an admission plasma glucose value in the T2D range. The authors were able to conduct secondary confirmatory tests upon discharge in 70% of the participants; 60% of these patients were diagnosed with T2D.[40] Another study, in the US, used A1C test in emergency department to measure the rate of undiagnosed T2D among patients with acute illness. They found previously undiagnosed T2D in 9% of patients.[39] Of those aged 45 years and older, 70% had newly diagnosed dysglycemia, while 55% of those aged 30 to 44 years were found to have newly diagnosed dysglycemia. Of those aged 18 to 29 years, 33% were newly diagnosed with dysglycemia. Furthermore, researchers in Germany estimated the prevalence of T2D in patients (55 years of age and older) who were admitted to the hospital using A1C test. Of the 5820 patients registered, 32.7% had a known history of T2D, whereas 9.5% had previously undiagnosed T2D. Patients with previously undiagnosed T2D were admitted to hospital predominantly for cardiac disorders (21.9%), nervous system disorders such as cerebral infarction (15.0%), and infections/infestations (13.4%).[42]

Other studies have looked at the prevalence of undiagnosed T2D among patients presenting to the hospital with chronic conditions such as heart disease, stroke and kidney disease. Patients hospitalized with acute heart failure had a 27.9% prevalence of T2D,

half of which were previously undiagnosed.[131] Another study found that the prevalence of T2D was 62% in patients with heart issues, of which 40% had diagnosed T2D and 22% had undiagnosed T2D.[132] In acute stroke patients, almost two-thirds were classified as having T2D; 21% had diagnosed T2D, 15% had undiagnosed T2D, and 27% had pre-T2D at a 12 week follow-up.[133] In patients with acute coronary heart disease, the prevalence of T2D was 48.4%, of which 31.8% had known history of T2D and 16.6% had newly diagnosed T2D.[134] Lastly, amongst patients diagnosed with chronic kidney disease – after adjusting for age, sex, and ethnicity – 32.9% had diagnosed T2D, 24.2% undiagnosed T2D, and 17.1% had pre-T2D.[135] These studies demonstrate that a significant portion of patients with chronic illness have undiagnosed and therefore untreated T2D. This can be detrimental for the overall health and recovery of the patients.

2.8 Summary

Diabetes can have profound impacts on patients as well as our healthcare system. Some patients with T2D may go undiagnosed and untreated, which may lead to complications including hospitalization. However, there remains limited research of Canadians with undiagnosed T2D. While a decline in the percentage of T2D hospitalizations has been observed until 2011 in Canada, no Canadian literature exists on how the percentage of T2D hospitalizations among undiagnosed T2D patients has changed over time. It is also important to study the factors associated with undiagnosed T2D requiring hospitalization and whether these determinants differ for males and females.

The overall objective of this thesis is to investigate the percentage of Canadian men and women who report no previous T2D diagnosis and whom experience a T2D related hospitalization. Specifically, there are three objectives:

Objective 1: Identify the percentage of men and women in Canada who report no previous T2D and experience a T2D related hospitalization.

Hypothesis: The percentage of individuals with unreported T2D has been estimated to be 1.13%-3.09% of general population with men at higher risk.[80] It is hypothesized that T2D hospitalizations will be higher among men compared to women.

Objective 2: Explore temporal trends of T2D related hospitalizations among Canadian men and women with unreported T2D.

Hypothesis: With increasing rates of obesity observed in Canada,[92,93] incidence of new T2D might also increase. Which can lead to no change observed in the crude prevalence of T2D despite the increase in detection rate. It is hypothesized that that percentage of T2D related hospitalizations among unreported T2D patients will remain constant for both men and women.

Objective 3: Explore the role of sociodemographic, health-related and behavioural predictors associated with T2D related hospitalization among Canadian men and women with unreported T2D.

Hypothesis: The factors previously associated with T2D related hospitalization will be associated with unreported T2D hospitalization. These factors include age, visible minority, marital status, education, income, household size, rurality, BMI, self-reported health, having a regular doctor, visiting doctor in past 12 months, alcohol drinking, smoking tobacco, physical activity, and fruits and vegetable consumption. The risk factors and the magnitude of the effect will differ for men and women.

Chapter 3

3 Methods

This chapter will first describe in detail the datasets used for this project: Canadian Community Health Survey and Discharge Abstract Database. The target population and data collection methods will be summarized for each database. This linkage process will also be explained. Additionally, this chapter will explain how the outcome variable and the explanatory variables are constructed. Lastly, this chapter will lay out the analysis for each objective of this thesis.

3.1 Linked datasets

In 2012, Statistics Canada approved the linkage of the Canadian Community Health Survey (CCHS) 2000-2011 to the Discharge Abstract Database (DAD) 1999-2012.[136] The purpose of this record linkage was to better understand and quantify the association between behavioural, socio-economic, environmental risk factors, hospitalizations and health outcomes at the individual and population level.[136] The DAD and the CCHS are complementary sources of data. The DAD contains information on diagnosis and intervention for each hospitalization event; however, the DAD does not contain information on determinants of health, such as socioeconomic and lifestyle factors.[136] Alternatively, the CCHS contains a rich source of information on health status and determinants of health, but lacks the detail needed to study hospitalization events.[136] Linking the DAD with the CCHS enables a more comprehensive understanding of what brings Canadians in contact with acute care facilities.[136] Statistics Canada ensures respondent privacy during linkage and subsequent analysis of linked files.[136] Only employees directly involved in the linkage process can access the identifying information.[136]

3.1.1 Canadian Community Health Survey

The CCHS is a cross-sectional survey that collects information related to health status, health care utilization and health determinants for the Canadian population.[137] Data collection for the survey began in 2000 and was repeated every two years.[137] Starting

in 2007, data for the CCHS were collected annually instead of every two years.[137] While a sample of approximately 130,000 respondents were interviewed during the survey cycles 1.1, 2.1 and 3.1, the sample size was changed to approximately 65,000 respondents each year starting in 2007.[137]

3.1.1.1 Population

The CCHS covers the population 12 years of age and over living in the ten provinces and the three territories.[137] Excluded from the survey's coverage are: persons living on reserves and other Aboriginal settlements in the provinces, full-time members of the Canadian Forces, the institutionalized population, children aged 12 to 17 living in foster care, and persons living in the Quebec health regions of Région du Nunavik and Région des Terres-Cries-de-la-Baie-James.[137] Altogether, these exclusions represented less than 3% of the Canadian population aged 12 and over.[137] The CCHS respondents who consented to share and link their survey information with provincial and federal health ministries were eligible for linkage. Approximately 84.7% of respondents living outside of Quebec agreed to share and link their data.[136]

3.1.1.2 Data collection

Before data collection begins for the CCHS, a sample size is calculated to provide reliable estimates at the provincial and health region (HR) level.[138] It also takes into account any non-response and vacant or out of scope households.[138] First, the sample is allocated among provinces proportional to their size and the number of HRs in each province.[138] Each province's sample is then allocated among its HRs proportionally to the square root of the population in each HR.[138] Data collection for the CCHS is done over the telephone or in person, by either computer assisted personal or computer assisted telephone interviewing techniques.[137] The interview lasts approximately 45 minutes.[137] The CCHS response rate ranged from 73% to 85% during data collection period of 2001 to 2009.[139,140]

To ensure better coverage of the target population, two sampling frames are used: an area frame and a telephone frame.[138] The area frame is an adaption of the Canadian Labour Force Survey which uses a multistage stratified cluster design.[138] The sample is taken

through a three-stage sampling process (illustrated in Figure 3.1). First, using geographic, economic, and demographic information, the entire country is divided into strata.[138] Each stratum is divided into clusters, which is the primary sampling units. The first stage of the sample process consists of the selection of these clusters within each stratum.[138] In the second stage of sampling, within each selected cluster, a sample of households is drawn from a list.[138] The third stage of sampling is the selection of individuals within a selected household.[138] Either one or two people are selected depending on the household composition; two persons are selected from large households containing members in the 12 to 19 years old age group.[138]

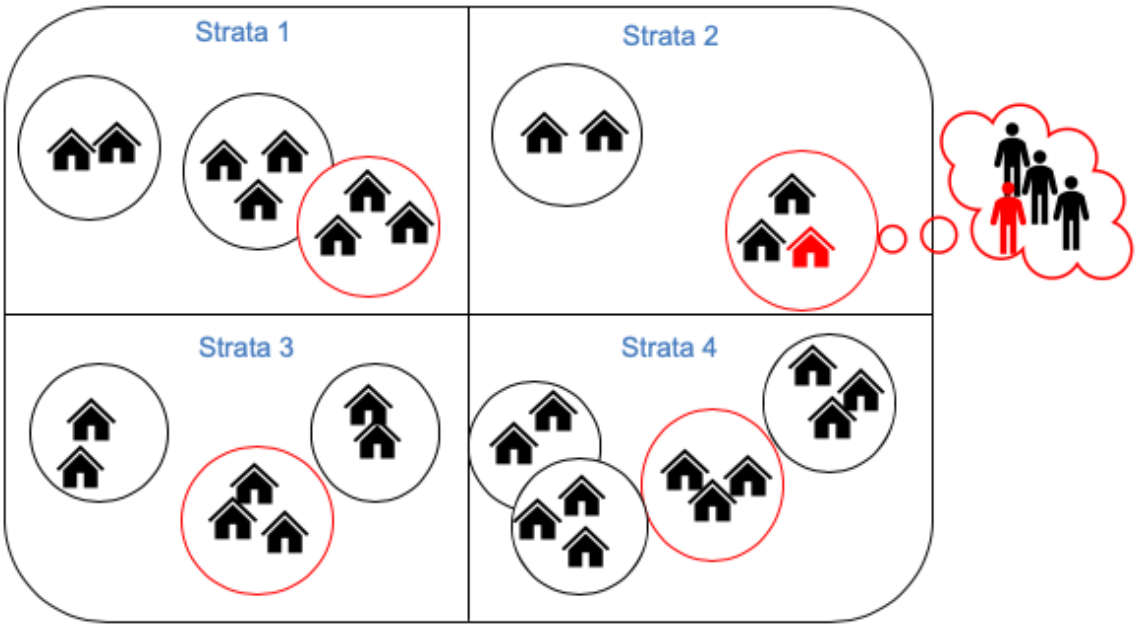


Figure 3.1: Illustration of CCHS sampling method

In some HRs, a Random Digit Dialing (RDD) sampling frame or a list frame of telephone numbers was used. The telephone frame originally consisted of RDD frame of telephone numbers.[138] This method involved section of working telephone bank (area code and the first 5 digits of the telephone number).[138] Then numbers from 00 to 99 were generated at random to create a complete phone number.[138] However, due to low hit rates, a list frame was used which consisted of a simple list of phone numbers.[141] Conversely, the disadvantages of the list frame were: confidential and unlisted numbers were missing, and the list can quickly be outdated as people move. However, it increased

the hit rates significantly.[141] In the first CCHS cycle, 83% of sample household came from an area frame. Approximately, 7% of the sample of households came from the RDD frame, while 10% of the sample was generated from the list frame. This changed to 49%, 50% and 1% of the sample coming from area frame, RDD, and list frame, respectively, in the following cycles.[142,143]

3.1.2 Discharge Abstract Database

The DAD is a national Canadian database created by the CIHI.[144] This database includes all separations from hospitals (including discharge, death, sign-outs and transfer) that occur during a fiscal year (April 1 to March 31).[144] Each abstract includes information on diagnostic codes, intervention provided and patient demographic and administrative information.[144] Data from Quebec are not included in the DAD.[144]

3.1.2.1 International Statistical Classification of Diseases and Related Health Problems

The DAD uses the International Statistical Classification of Diseases and Related Health Problems (ICD) to report diagnosis. The ICD is a coding system for reporting disease and health conditions.[144] It was developed by the World Health Organization and was endorsed by the world health assembly in 1990.[145] The International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM)[146] and the International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Canada (ICD-10-CA) are enhanced version of the 9th and 10th revision of ICD appropriate for Canadian use.[147] In 2001–2002, the format of the DAD abstract was changed to accommodate the adoption of the ICD-10-CA classification systems in some provinces and territories; before which ICD-9-CM was used.[144] The coding system was updated as the ICD-9 was no longer descriptive enough to precisely reflect the state of patients' diseases. For instance, the ICD-9 system had 13,000, three to five-digit codes and did not have the capacity to expand.[148] The ICD-10 system has 68,000 codes that are three to seven digits each and has the capacity to expand.[148] Since 2004–2005, all provinces and territories submitted data to CIHI using the ICD-10-CA abstract.[144] Table 3.1 shows the implementation year of ICD-10-CA by each province and

territory.[144] When performing analyses over time or across provinces and territories, users should note that data element specifications have changed between fiscal years and appropriate coding scheme should be used.

Table 3.1: The year of Implementation of ICD-10-CA by Province and Territories

Province/ Territory	2001-2002	2002-2003	2003-2004	2004-2005	2006-2007
N.L.	**ICD-10-CA/CCI**	ICD-10-CA/CCI	ICD-10-CA/CCI	ICD-10-CA/CCI	ICD-10-CA/CCI
P.E.I	**ICD-10-CA/CCI**	ICD-10-CA/CCI	ICD-10-CA/CCI	ICD-10-CA/CCI	ICD-10-CA/CCI
N.S.	**ICD-10-CA/CCI**	ICD-10-CA/CCI	ICD-10-CA/CCI	ICD-10-CA/CCI	ICD-10-CA/CCI
B.C.	**ICD-10-CA/CCI**	ICD-10-CA/CCI	ICD-10-CA/CCI	ICD-10-CA/CCI	ICD-10-CA/CCI
Y.T.	**ICD-10-CA/CCI**	ICD-10-CA/CCI	ICD-10-CA/CCI	ICD-10-CA/CCI	ICD-10-CA/CCI
Sask.	**ICD-10-CA/CCI (partial)**	**ICD-10-CA/CCI (full)**	ICD-10-CA/CCI	ICD-10-CA/CCI	ICD-10-CA/CCI
Ont.	ICD-9-CM	**ICD-10-CA/CCI**	ICD-10-CA/CCI	ICD-10-CA/CCI	ICD-10-CA/CCI
Alta.	ICD-9-CM	**ICD-10-CA/CCI**	ICD-10-CA/CCI	ICD-10-CA/CCI	ICD-10-CA/CCI
N.W.T.	ICD-9-CM	**ICD-10-CA/CCI**	ICD-10-CA/CCI	ICD-10-CA/CCI	ICD-10-CA/CCI
Nun.	ICD-9-CM	**ICD-10-CA/CCI**	ICD-10-CA/CCI	ICD-10-CA/CCI	ICD-10-CA/CCI
N.B.	ICD-9-CM	ICD-9-CM	**ICD-10-CA/CCI**	ICD-10-CA/CCI	ICD-10-CA/CCI
Man.	ICD-9-CM	ICD-9-CM	ICD-9-CM	**ICD-10-CA/CCI**	ICD-10-CA/CCI
Que.	ICD-9-CCP	ICD-9-CCP	ICD-9-CCP	ICD-9-CCP	**ICD-10-CA/CCI**

The ICD-9-CM diagnosis codes are composed of codes with three, four, or five digits. The first three digits are included as the heading of a category of codes that may be further subdivided.[149] Diabetes codes fall under the category 250.[149] The fourth digit identify complications/manifestations associated with diabetes.[149] See Table 3.2 for details on how diabetes complications/manifestations are categorized in the fourth digit.[149] A fifth digit is required for all category 250 codes to identify the type of

diabetes and whether the diabetes is controlled or uncontrolled.[149] See Table 3.3 for details on the categorization of diabetes types in the fifth digit.[149] Diabetic conditions can be assigned additional codes for associated conditions. In this case, the code from category 250 is sequenced before the codes for the associated conditions.[149] Secondary codes include diabetic retinopathy (362.0) and diabetic macular edema (362.07); however, these codes are coupled with codes from category 250.[149]

Table 3.2: ICD-9-CM codes for diabetes complications/manifestations

Description	ICD-9-CM code
Diabetes without mention of complications	250.0X
Diabetes with ketoacidosis	250.1X
Diabetes with hyperosmolarity	250.2X
Diabetes with other coma	250.3X
Diabetes with renal manifestations	250.4X
Diabetes with ophthalmic manifestations	250.5X
Diabetes with neurological manifestation	250.6X
Diabetes with peripheral circulatory disorders	250.7X
Diabetes with other specified manifestations	250.8X
Diabetes with unspecified complications	250.9X

Table 3.3: ICD-9-CM codes for type of diabetes

Description	ICD-9-CM code
Type 2 diabetes – not stated as uncontrolled	250.X0
Type 1 diabetes – not stated as uncontrolled	250.X1
Type 2 diabetes – uncontrolled	250.X2
Type 1 diabetes – uncontrolled	250.X3

In general, ICD-10-CA codes can be up to seven characters long and are designed as follows: XXX.XXX.X (category.anatomic site/severity.extension).[148] The first level of categorization is the type of diabetes (see Table 3.4).[148] Then the level of control is indicated by the number after the decimal point.[148] Each numerical code after the decimal point, numbering 1 through 9, describes a different complication (see Table 3.5).[148] The fifth and sixth characters identify specific types of manifestation.[148]

Table 3.4: ICD-10-CA codes for type of diabetes

Description	ICD-10-CA code
Diabetes mellitus due to underlying condition. * This code is for diabetes caused by diseases such as cancer, pancreatitis, or nutritional deficiencies	E08.XXX
Drug or chemical induced diabetes mellitus	E09.XXX
Type 1 diabetes mellitus	E10.XXX
Type 2 diabetes mellitus	E11.XXX
Other specified diabetes mellitus. * This code is for genetic defects of β-cell function and insulin action or post-pancreatectomy diabetes	E13.XXX
Unspecified diabetes	E14.XXX

Table 3.5: ICD-10-CA codes for diabetes complications

Description	ICD-10-CA code
Type 2 diabetes with coma	E11.0XX
Type 2 diabetes with ketoacidosis	E11.1XX
Type 2 diabetes with renal complications	E11.2XX
Type 2 diabetes with ophthalmic complications	E11.3XX
Type 2 diabetes with neurological complications	E11.4XX
Type 2 diabetes with peripheral circulatory complications	E11.5XX
Type 2 diabetes with other specified complications	E11.6XX
Type 2 diabetes with multiple complications	E11.7XX
Type 2 diabetes with unspecified complications	E11.8XX
Type 2 diabetes without complications	E11.9XX

3.1.2.2 Population

Approximately 75% of all hospital separations are represented in the DAD.[144] Quebec's hospital separations are submitted to CIHI via Quebec's ministère de la Santé et des Services sociaux once per year and is included in the Hospital Morbidity Database (HMDB), but not in the DAD; this usually accounts for 25% of total hospital separations.[144] The DAD contains record of hospital activity that is completed for each event of a hospital separation, meaning that a patient can have multiple records.[144]

3.1.2.3 Data collection

The DAD collection process works as such: first, a patient presents to an acute care facility, information is then collected on the patient and necessary diagnosis and interventions are made by the health care team, the information is recorded in the

institutional health record system, and this information is then submitted to the CIHI annually.[144] The data goes through quality control measures to ensure that it is in the expected format, falls within a set range; errors are flagged, and missing data is represented via blanks or numerical values.[144] Hospitals may be asked to submit corrections.[144] Every year, enhancements are made to the database to address emerging health care issues, address client needs, and improve data quality.[144] Support is provided by the CIHI to assign data collectors with questions related to the DAD products and provide educational programs on coding and abstracting, how to manage submission errors and corrections, and other related topics.[144] Adherence to the data submission and abstracting standards described in the manual helps to ensure that the DAD reports accurately reflect the institution's activities.[144] Adherence is obtained through the application quality control edits, education sessions and ongoing client support.[144] If data is not received from a particular institution, that institution is contacted by the CIHI, if necessary.[144]

3.2 Linking the Canadian Community Health Survey to the Discharge Abstract Database

There are two types of linkage methods: deterministic and probabilistic.[150] Deterministic linkage is the process of linking datasets using an identifier that is unique to each participant.[150] There are two possible outcomes of deterministic linkage: 1) participants who are an exact match are linked, and 2) unmatched participants who do not get linked.[150] In contrast, probabilistic linkage uses multiple, possibly non-unique, identifiers to link datasets.[150] Probabilistic record linkage requires the creation of a file which compares all records in one dataset with those in the other dataset.[150] Following the linkage, an agreement pattern is determined for each comparison and there may be partial or full agreement on the identifiers selected for linkage.[150]

The theory of probabilistic record linkage works on the principle that, when two records are compared, the results of certain agreement patterns are representative of truly linked pairs, while other agreement patterns are representative of truly unlinked pairs.[150] A numerical value is assigned to reflect the agreement of the two records, which is derived using conditional probabilities.[150] For the CCHS-DAD linkage file, which uses

probabilistic linkage, this numerical value was a weight based on the ratio of the estimated probability of the outcome occurring for true matches, to the estimated probability of the outcome occurring for non-matches.[151] Researchers then set a threshold for determining the linkage status of any two comparisons.[150]

The CCHS records were linked to hospitalization records using probabilistic methods based on the following common identifiers: date of birth, postal code, sex, province and Health Insurance Number (HIN).[151] The CCHS file was first linked to the tax data file (HSTF).[151] This allowed researchers to identify respondents having more than one postal code during 1996-2012.[151] Eligible CCHS respondents who agreed to share their data (84.7% = 564,676) were then linked to 49,098,733 hospital records between April 1, 1999 through March 31, 2013.[151] A total of 1,188,537 hospitalizations were linked to CCHS respondents. Overall, 57.5% of CCHS respondents were linked to at least one hospital record.[151]

False Positive Rate (FPR) and False Negative Rate (FNR) were calculated for the linkage.[151] A clerical review of a probabilistic sample of 4,590 record-pairs was examined by three independent reviewers.[151] The links are reviewed, and a decision was made to accept or reject the pair as definitive.[151] For each pair, the review was based on the comparison of date of birth, postal code, sex, province and HIN.[151] The final clerical decision was based on the majority vote.[151] The FPR was 0.06% and the FNR was 2.09%.[151]

3.3 Data setup

The population of interest for this study was individuals who at the time of the CCHS interview reported no previous diagnosis of T2D, who were 18 years of age and older, were not pregnant at the time of the interview, resided outside Quebec, and were not proxy interviews. For the purpose of this project, six cohorts of CCHS respondents who met the inclusion and exclusion criteria (CCHS 1.1 [2000 to 2001], CCHS 2.1 [2003 to 2004], CCHS 3.1 [2005 to 2006], CCHS 2007, CCHS 2008 and CCHS 2009) were followed forward in time in the DAD from the date of the CCHS interview. To achieve

this, each CCHS cohort was linked to subsequent years of DAD files using unique identifiers provided by Statistics Canada.

Each respondent was followed for three years in the DAD starting from the CCHS interview date. An assumption was made that if a CCHS respondent reported no diagnosis of T2D at the time of their CCHS interview and was hospitalized within three years for a T2D related condition, it is likely they had undiagnosed T2D when the CCHS interview was conducted. A three-year follow-up period was chosen as the best compromise between diabetes development and progression, and the longest time we can assume an individuals had diabetes before diagnosis. Also, the assumption was made that self-reporting undiagnosed diabetes is an accurate measure of undiagnosed diabetes.

Only the first T2D related hospitalization event was considered for this study. Figure 3.2 illustrates how respondents in the CCHS followed for three years can either have single hospitalization events (respondents G and I), multiple hospitalization events (respondents A, C, E, L), or no hospitalization events (respondents B, D, F, J, K). These hospitalization events can be for different health conditions, including T2D.

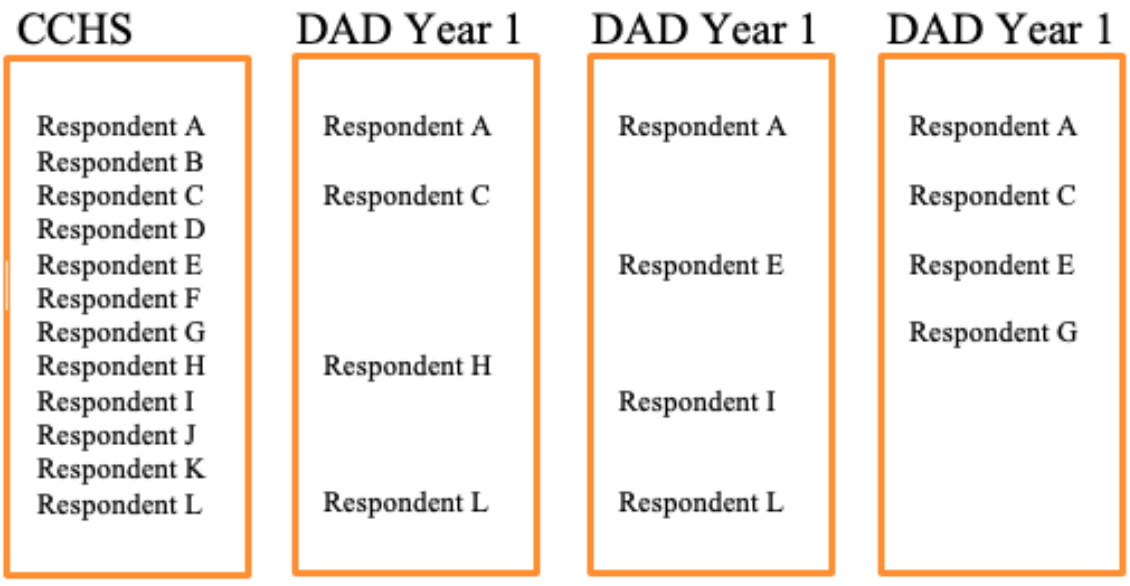
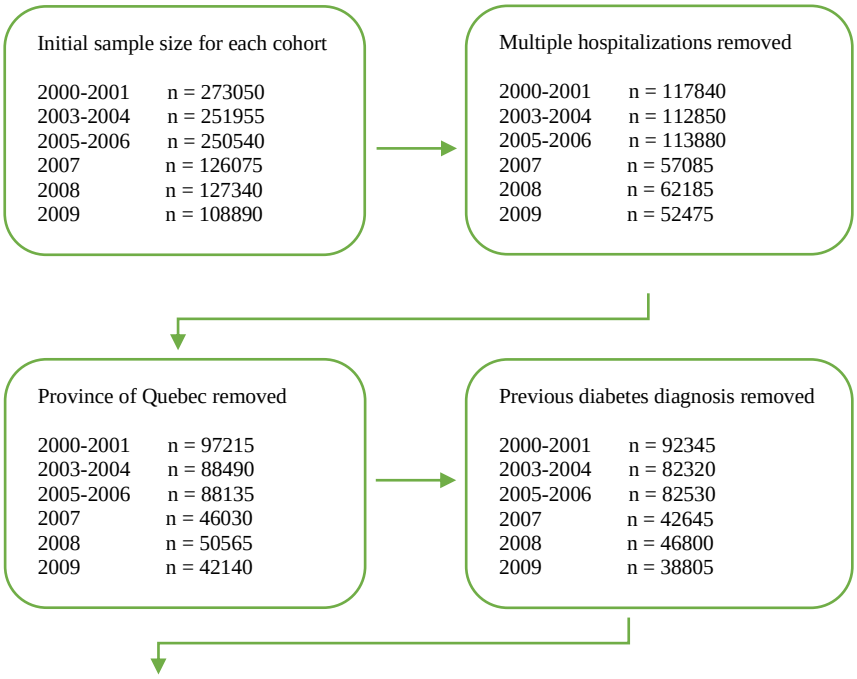


Figure 3.2: Illustration of multiple hospitalizations

A hospitalization event can lead to several diagnoses. For instance, a person might be hospitalized for a hip fracture (primary diagnosis) might also be diagnosed with T2D and high blood pressure as a secondary diagnosis. Up to 25 diagnostic codes can be entered per hospitalization event. For the purpose of this study, a hospitalization with at least one ICD code for diabetes, appearing as any of the 25 diagnostic codes, was considered a T2D related hospitalization. Therefore, diabetes might have not be the primary reason for hospitalization.

Respondents from the province of Quebec were removed. Any CCHS respondents who at the time of survey reported having diabetes were also removed. Only respondents 18 years of age and older were included in the study. The reason for limiting the study to this age group is that the effects of health behaviours on health-related outcomes may manifest differently in adolescents and adults (see objective #3).[152–155] Furthermore, the population was limited to non-pregnant individuals. CCHS respondents whose data were collected by proxy interviews were excluded due to a low reliability for questions regarding health behaviours asked by proxy, as demonstrated in previous research.[156] Figure 3.3 illustrates the change in sample size of the linked CCHS-DAD datafile as each criterion was applied.



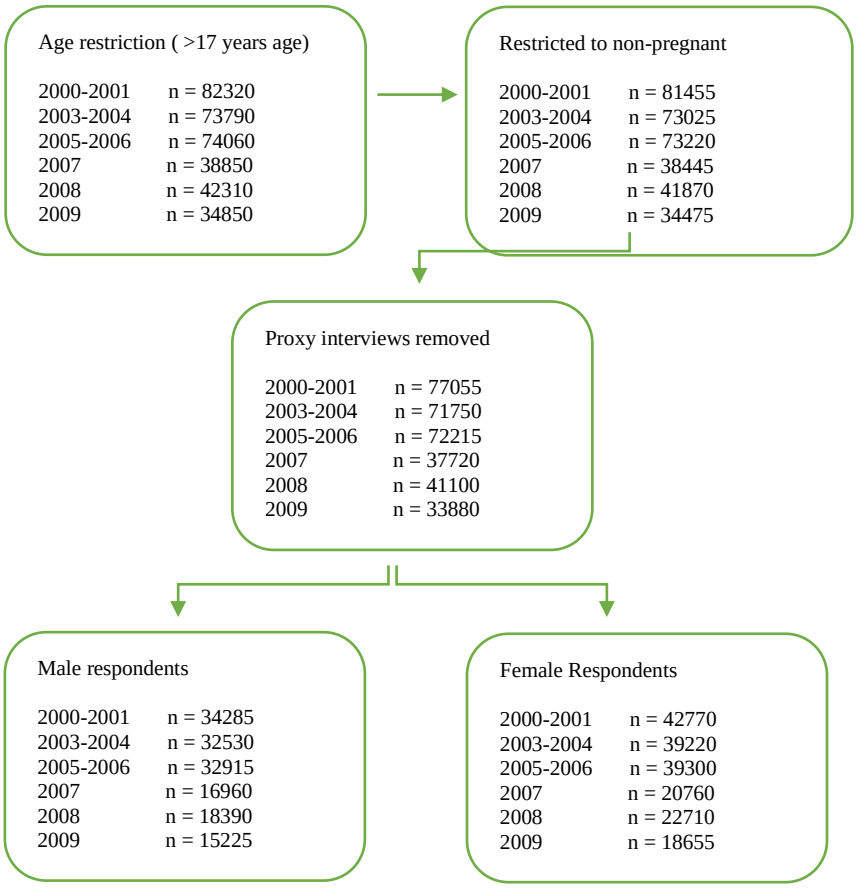
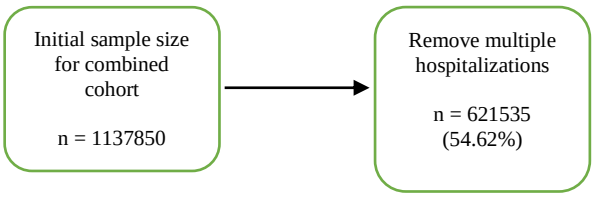


Figure 3.3: Inclusion and exclusion criteria – remaining sample size by cohort

As displayed in Figure 3.4, an initial combined sample of 1,137,850 was obtained after linking the DAD files to each of the six CCHS cohort. As only the first T2D related hospitalization record was used, this resulted in the removal of 621, 535 records or 54.62% of the sample size. Another 182,595 records were removed due to other exclusion criteria (see Figure 3.4). A total of 333,720 of the CCHS respondents met the inclusion criteria (i.e., had no previous diagnosis of T2D, were 18 years or older, were not pregnant at the time of the interview, resided outside Quebec, were not proxy interviews, and agreed to share their file between CCHS 1.1 2000/2001 – CCHS 2009).



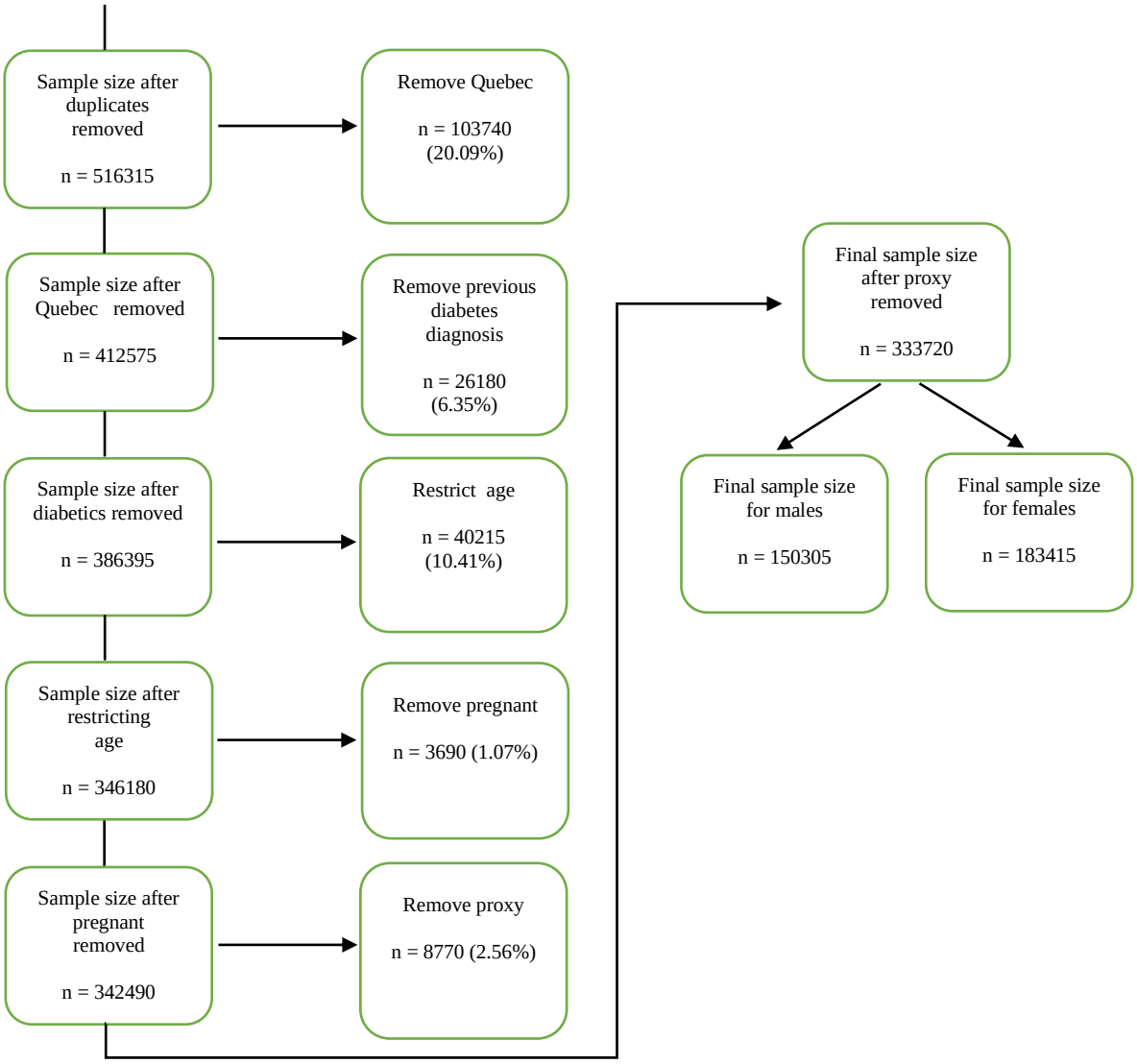


Figure 3.4: Inclusion and exclusion criteria – remaining total sample size and percent removed

3.4 Missing data

Missing data can be divided into three categories. First, values missing completely at random (MCAR) are not associated with the values of other variables or the missing values itself.[157] Estimated parameters are not biased by this type of missing pattern.[157] Second, missing at random (MAR) is the probability that the missing values are associated with the observed values, but are not related to the specific missing values.[157] Lastly, missing not at random (MNAR) can bias parameter estimates and

can occur for two possible reasons: 1) missing values depend on the missing values itself;[157] for example, people who have higher income are less likely to report it, or 2) missing values are dependent on other variables;[157] for example, females do not want to disclose their body weight, therefore, the value of weight is impacted by sex.[157]

Missing values are generated due to non-response to some or all questions in the CCHS.[158] Some reasons for non-response in the CCHS include refusal to answer some or all questions, not knowing the answer, and skipping patterns of the questionnaire. In addition, some questions might be asked in specific years, or they might be asked only of a specific demographic group.[158] There are two types of non-response: total non-response and partial non-response.[158] Total non-response happens when all variables are missing for a person due to complete refusal to participate in the survey or interviewers are unable to contact the respondent.[158] This is usually accounted for by adjusting the sampling weights at Statistics Canada.[158] Partial non-response is when some values are missing for a participant due to refusal to answer specific questions, participants not knowing the answers, and unavailability of data due to skipping patterns.[158]

There are multiple approaches to handling partial non-response. For this study, I utilized multiple imputation method. In multiple imputation, the missing values are substituted with a set of plausible values which contain the natural variability of the right value.[159] Missing data is predicated using observed data and the missing values are replaced with the predicted value.[159] This process is repeated multiple times creating multiple datasets. Each dataset is analyzed separately using standard statistical procedures. The analysis results are then combined to produce a single overall estimate.[159] For this study, 20 imputations were conducted in order to achieve more consistent estimates and standard errors.[160]

3.5 Measurement

The outcome variable for this study was T2D related hospitalizations. A number of explanatory variables were selected as potential predictors of T2D related hospitalization based on previous literature and availability of information in the CCHS. The explanatory

variables selected for comparisons are as follows: age, visible minority, marital status, education, income, household size, rurality, BMI, self-reported health, having a regular doctor, visiting doctor in past 12 months, alcohol drinking, smoking tobacco, physical activity, and fruits and vegetable consumption. The explanatory variables were broken down into three groups: sociodemographic, health-related and behavioural predictors. Some categorical variables were collapsed to binary variables. Lastly, survey design variables (mode of interview, year of interview) were used to adjust for differing survey conditions.

3.5.1 Outcome variable – type 2 diabetes related hospitalization

To ascertain T2D related hospitalization amongst individuals with unreported T2D, the population of interest was followed in the DAD for three years following their interview date. If a diagnosis code for T2D (primary or secondary) occurred during the three-year follow-up period, respondents were coded as having T2D related hospitalization. If respondents were not hospitalized or were hospitalized for other conditions, they were coded as not having T2D related hospitalization.

The diagnosis codes were based on the ICD-9-CM and ICD-10-CA for T2D due to changes in diagnosis coding in the DAD over time. For ICD-9-CM, category 250.X0 and 250.X2 (X = 0 through 9) were selected. For ICD-10-CA, E11.XXX.X (with any anatomic site/severity and extension) were selected. All diagnoses, up to 25 diagnostic codes per hospitalization event, were considered.

3.5.2 Sex

Sex is a binary variable in the CCHS. Interviewers entered in the sex of the respondent during initiation of the interview. If necessary, interviewer asked the sex of the participants. This is coded as *male* and *female*. No missing values were observed for this variable. The analyses were stratified by sex.

3.5.3 Sociodemographic predictors

Sociodemographic variables include age, visible minority, marital status, education, income, household size and rurality. These variables have been previously linked to T2D

or T2D related hospitalization among individuals diagnosed with T2D. For example, the proportion of patients hospitalized for T2D related complications has been shown to increase with age.[118] Furthermore, there is evidence to suggest the adjusted odds of hospitalization for both males and females followed a parabolic path.[122] Additionally, non-white individuals[122] and non-married individuals have been found to have higher T2D related hospitalizations.[161] Individuals in the lowest income and education quintile are more likely to have an a T2D hospitalization event than those in the highest quintile.[120] Household size was included to reflect how many individuals in the household depend on the income.[162] Lastly, living in rural areas has also shown to affect hospitalization events.[44]

3.5.3.1 Age

Age is a continuous variable and is based on the CCHS respondents date of birth. For the purpose of this study, age was centered at 18 and coded into deciles. The age variable was squared and used in the regression model as a quadratic predictor alongside a linear age variable. No missing values were observed for this variable.

3.5.3.2 Visible minority

In the CCHS, two questions are asked to determine the respondent's visible minority status. First respondents are asked, “Are you an Aboriginal person, that is, First Nations, Métis or Inuk (Inuit)?”. Non-aboriginal respondents are further asked to classify themselves as part of one or more racial or cultural groups on the following list: *White, South Asian* (e.g., East Indian, Pakistani, Sri Lankan etc.), *Chinese, Black, Filipino, Latin American, Arab, Southeast Asian* (e.g., Vietnamese, Cambodian, Malaysian, Laotian, etc.), *West Asian* (e.g., Iranian, Afghan, etc.), *Korean* and *Japanese*. For the purpose of this study, a binary variable was created. One group was classified as *white* and visible minority, including Aboriginal, were grouped as *non-white.* Non-respondents were coded as missing to be imputed.

3.5.3.3 Marital status

Marital status is a categorical variable in the CCHS. Respondents were asked to classify themselves into one of the six categories: *married, common-law, widowed, separated, divorced* and *single and never married.* For the purpose of this study, this variable was dichotomized. *Married* and *common-law* were grouped together as *married*. *Widowed, separated,* and *divorced* were group as *not married*. No missing values were observed for this variable.

3.5.3.4 Education

The following question was used to determine the level of education achieved by the CCHS respondents: "what is the highest degree, certificate or diploma you have obtained?" Possible answers included: *Less than secondary school graduation, secondary school graduation, some post-secondary, post-secondary* and *graduate*. For the purpose of this study, a dichotomous variable was created with the following categories: *less than secondary school* and *secondary school or more*. Non-response was coded as missing to be imputed.

3.5.3.5 Income

Income was a derived variable based on respondents answer to the question: "What is your best estimate of the total income, before taxes and deductions, of all household members from all sources in the past 12 months?". If respondents did not answer the question, they were asked to estimate which of the following groups their household income fell into: *less than $5,000 or $5,000 or more, less than $10,000 or $10,000 or more, less than $15,000 or $15,000 or more, less than $20,000 or $20,000 or more, less than $30,000 or $30,000 or more, less than $40,000 or $40,000 or more, less than $50,000, $50,000 to less than $60,000, $60,000 to less than $80,000, $80,000 to less than $100,000,* and *$100,000 or more*.

The CCHS categorized total household income from the above questions. Possible categorizations in CCHS 1.1 were *no income, less than $5000, $5000 to $9999, $10,000 to $14,999, $15,000 to $19,999, $20,000 to $29,999, $30,000 to $39,000, $40,000 to*

$49,000, $50,000 to $59,999, $60,000 to $79,999 and *$80,000 or more*. However, the categories were expanded over time to include *$60,000 to $69,000, $70,000 to $79,999, $80,000 to $89,999, $90,000 to $99,999, $100,000 to $149,999* and *$150,000 or more*. For the purpose of keeping this variable consistent throughout the survey collection period, the categorizations were standardized to the CCHS 1.1. Non-response to this variable was coded as missing for imputation.

3.5.3.6 Household size

The CCHS includes variable that indicates the number of people living within a household. This variable was a continuous variable with values ranging from 1 to 28. This variable was recoded to include *one, two, three, four, five, six or more*. There were no missing values on this variable.

3.5.3.7 Rurality

Respondents in the CCHS were categorized into *rural* or *urban* based on their postal code. The CCHS described an urban area as continuously built-up and not having discontinuity exceeding two kilometers. Urban areas were also categorized as having a population concentration of 1,000 or more and a population density of 400 or more per square kilometer. This was based on the most recent census information.[163] This variable did not have any missing information

3.5.4 Health-related predictors

These predictors include BMI and self-reported health. There has a been a strong association found between BMI and T2D. Hospitalizations related to T2D have also been linked to BMI.[118] Furthermore, T2D can be linked to several other health conditions, with worse health status predicting hospitalization events.[123]

3.5.4.1 Body mass index

In order to derive BMI, the height and weight of the participants was used. In the CCHS, respondents are asked to disclose their height and weight. These values can be expressed in either inches or centimeter and pounds or kilograms. All values are converted to metric

units by CCHS. The following formula was used to calculate respondents' BMI: BMI=kg/m^2. Any missing values for height or weight generated missing value for BMI. This was flagged as missing for imputation purposes.

3.5.4.2 Self-perceived health

Respondents were asked, "In general, would you say your health is excellent, very good, good, fair, or poor?". A binary variable was created with *excellent, very good, good* categorized as *good* and *fair or poor* categorized into *poor*. Respondents who did not answer this question were flagged and missing values were imputed

3.5.5 Behavioural predictors

Behavioural predictors include having a regular doctor, visiting doctor in past 12 months, alcohol drinking, smoking tobacco, physical activity, and fruits and vegetable consumption. These variables have previously been linked to T2D and T2D hospitalization. Increased use of primary care among T2D patients has been associated with increased risk of a subsequent hospitalization.[128] Primary care use has also been associated with T2D hospitalizations.[123] An increased risk of hospital admissions in smokers and physically inactive participants has been found.[129] In contrast, regular alcohol drinkers have been shown to have lower hospitalization rates than did occasional or non-drinkers.[123] Lastly, eating a diet high in fruits and vegetables has been associated with lower hospitalization rates for T2D.[164]

3.5.5.1 Having a regular doctor

All respondents in the CCHS were asked, "Do you have a regular medical doctor?" Respondents could answer *yes* or *no*. Respondents who did not know the answer or refused to answer were flagged as missing for imputation.

3.5.5.2 Visiting doctor in past 12 months

The CCHS asks respondents, "During the past 12 months, how many times have you seen or talked to on the telephone, about your physical, emotional or mental health with a family doctor or a general practitioner?" Responses ranged from 0 to 366. For the

purpose of this study, this variable was categorized in to *visited doctor in past 12 months* and *did not visit doctor in the past 12 months*. Non-responses to this question were flagged as missing for imputation.

3.5.5.3 Alcohol drinking

In the CCHS, respondents were asked the following questions about their drinking history: “have you ever had a drink?”; “have you drank in the past 12 months?”; and if so, “during the past 12 months, how often did you drink alcoholic beverages?” This information was used to derive a categorical variable that groups respondents into the following drinking categories: *regular drinker, occasional drinker and former drinker,* and *never drank*. *Regular drinkers* are defined as anyone who drinks at least once a month. *Occasional drinkers* are defined as individuals who drink less than once a month. *Former drinkers* consist of individuals who drank in their lifetime but not in the past 12 months. Lastly, *never drank* is defined as individuals who have not consumed alcoholic beverages in their lifetime.

For the purpose of this study, a binary variable was created. *Regular drinkers* and *occasional drinkers* were grouped as *current drinkers*. *Former drinkers* and *never drank* were grouped as *currently non-drinkers*. Respondents who did not answer were flagged as missing for imputation.

3.5.5.4 Smoking tobacco

In the CCHS, respondents were asked the following questions: 1) “In your lifetime, have you smoked a total of 100 or more cigarettes?”; 2) “Have you ever smoked a whole cigarette?”; 3) “At the present time do you smoke cigarettes daily, occasionally or not at all?; 4) “Have you ever smoked cigarettes daily?” Based on smoking habits, respondents were categorized into the following 7 categories: *daily smokers, occasionally but former daily smoker, always occasional smoker, former daily smoker non-smoker now, former occasional smoker nonsmoker now and never smoked*.

A dichotomous variable was created for the purpose of this study. *Daily, occasionally but former daily smoker,* and *always occasional smoker* were grouped together as *current*

smokers whereas *former daily smoker non-smoker now, former occasional smoker non-smoker now,* and *never smoked* were grouped together as *currently non-smokers*. Respondents who did not answer were flagged as missing.

3.5.5.5 Physical activity

Physical activity was measured using participants' self-reported frequency and duration of leisure physical activity within the three months prior to survey administration. In the CCHS, each type of physical activity (e.g., swimming, biking) was assigned a corresponding Metabolic Equivalent (MET) value - multiple of resting metabolic rate. For example, a MET value of 2 indicates twice the energy expended compared to rest. The volume of physical activity was calculated by multiplying the frequency and duration of each type of physical activity as well as the MET value of the activity to derive how much energy was expended daily. Higher MET values indicate higher volume of physical activity. Respondents who did not answer were flagged as missing for imputation.

3.5.5.6 Fruits and vegetable consumptions

Total fruit and vegetable consumption was based on responses to a series of questions regarding the frequency of consumption of specific types of fruits and vegetables. Participants were asked the following questions: "how often do you drink fruit juices such as orange, grapefruit or tomato?"; "how often do you usually eat fruit?"; "how often do you eat green salad?"; "how often do you eat potatoes, not including french-fries, fried potatoes, or potato chips?"; "how often do you usually eat carrots?"; "how many servings of other vegetables do you usually eat, not counting carrots, potatoes, or salad?" Participants could report on per day, per week, or per month bases. Average daily frequency of fruit and vegetable consumption was calculated for each participant as a continuous measure by first converting the numerical responses into average daily consumption and then adding the responses to the six questions. Respondents who did not answer were flagged as missing.

3.5.6 Survey design variables

Survey design variables included the year of the CCHS interview and mode of interview. As prevalence of T2D, management of T2D and polices around health care changed over time in Canada, it is important to consider how the year of data collection can impact T2D related hospitalizations. Additionally, when comparing two modes of interviewing, in-person interviews to telephone interviews, significant differences were found between two modes of interviews for some health indicators.[165] For example, obesity was significantly higher for in-person interviews (17.9%) than for telephone interviews (13.2%).[165]

3.5.6.1 Interview date

The CCHS records the date of the CCHS interview; this includes the day, month and year. A new variable was created, *year of interview*, to represent the year of the data collection ranging from 2000 to 2009. This variable was further centered at the year 2000, the first year of data collection for the first CCHS cohort, which results in the range of 0 to 9. The purpose for centering the variable at 2000 was so the intercept term in the regression model can be interpreted as the log-odds of T2D related hospitalization when the year of data collection is 2000.

3.5.6.2 Mode of interview

Mode of interview is a binary variable in the CCHS with *in-person* interview and *telephone interview* as the two options. Missing information on this variable was flagged for imputation

3.6 Statistical analysis

This study employed sex gender-based analysis (SGBA),[166] an approach that examines diversity between males and females with the goal of contributing to more comprehensive knowledge that addresses differences between women and men. Male and female bodies have innate physiological differences that may contribute to the relationship between explanatory variables and T2D related hospitalization

differently.[167] There is research to suggest T2D related hospitalization rate differ between men and women.[33]

3.6.1 Descriptive statistics

Descriptive statistics were produced for both missing and imputed datasets to understand the basic characteristics of the combined six CCHS cohorts. The SURVEYFREQ procedure in SAS was used to produce population estimates and frequencies from survey data. This procedure utilizes bootstrap weights to takes into account the survey design to compute variance and confidence intervals.[168] The SURVEYFREQ procedure in SAS was used to compute a frequencies distribution table with 95% confidence intervals for nominal and ordinal variables. Frequency distribution was computed for the following categorical variables: mode of interview, visible minority, marital status, education, income, household size, rurality, self-reported health, having a regular doctor, visiting doctor in past 12 months, alcohol drinking, and smoking tobacco. The SURVEYMEANS procedure in SAS was used to produce population estimates means, standard deviation and corresponding 95% confidence interval (CI) for continuous variables. This procedure also estimates variance and confidence intervals taking into account the survey design.[169] Means and standard deviations were generated for the following variables: age, income, household size, BMI, physical activity, and fruits and vegetable consumption.

3.6.2 Analysis for objective 1

The first objective is to identify the percentage of men and women in Canada with unreported T2D who experience a T2D related hospitalization. Using SURVEYFREQ procedures, a frequency distribution table was created for the outcome variable *T2D related hospitalization* separately for males and female. Results were generated by pooling respondents from the six CCHS cohorts. This estimated the average percentage of T2D related hospitalization and corresponding confidence intervals between 2000 and 2009.

3.6.3 Analysis for objective 2

The second objective was to explore temporal trends of T2D related hospitalizations among Canadian men and women with unreported T2D. First, SURVEYFREQ procedures was used to produce percent of T2D related hospitalizations with corresponding confidence intervals for each year the CCHS survey was conducted. A bar graph was produced for the percentage of T2D related hospitalization in each year. Second, SURVEYLOGISTIC procedure was used to model the log-odds of T2D related hospitalizations based on the year of respondents' interviews. PROC SURVEYLOGISTIC fits linear logistic regression models for categorical response by the method of maximum likelihood. SURVEYLOGISTIC incorporates complex survey designs, including designs with stratification, clustering, and unequal weighting by using bootstrap weights.

3.6.4 Analysis for objective 3

The third objective was to explore the role of sociodemographic, health and behavioral risk factors associated with T2D related hospitalization among Canadian men and women with unreported T2D. Using SURVEYLOGISTIC, a linear logistic regression model was produced for males and females separately using the imputed datasets. The outcome variable was *T2D related hospitalization* and the explanatory variables were age, marital status, visible minority, education, income, household size, rurality, BMI, self-reported health, having a regular doctor, visiting doctor in past 12 months, alcohol drinking, smoking tobacco, physical activity, and fruit and vegetable consumption. Mode of interview and year of interview were included in the model to control for survey conditions. *MIANALYZE* was used to pool the results of each estimates from each imputed dataset. Odds ratios and confidence intervals were computed. Statistical significance was defined as a p-value < 0.05.

Mode of interview, visible minority, marital status, education, rurality, self-reported health, having a regular doctor, visiting doctor in past 12 months, alcohol drinking and smoking tobacco were treated as categorical variables in the logistics regression model. The reference groups are presented in Table 3.5. Whereas age, income, household size,

BMI, physical activity, and fruits and vegetable consumption were treated as continuous variables.

Table 3.6: Reference group for categorical variables

Variables	Reference Group
Type of interview	Telephone Interview
Visible minority	White
Marital status	Not married
Education	Less than secondary
Rurality	Urban
Self-reported health	Good
Having a regular doctor	No
Visit doctor in past 12 months	No
Alcohol drinking	currently non-drinker
Smoking tobacco	currently non-smoker

3.6.5 Sampling weights

The sample weight corresponds to the number of people in the population that are represented by each CCHS respondent. Standardized sample weights were applied to all statistical tests in order for the estimates produced by this study to be representative of Canadian population. Sampling probability differ between regions; therefore, weights are different from one person to another.[170]

3.6.6 Bootstrap weights

To ensure that results from the analysis of the CCHS data take into account complex design, bootstrap weights were used. The bootstrap method consisted of subsampling the initial CCHS sample and they were generated at statistics Canada. A simple random sample was selected, with replacement, from n-1 clusters within the n clusters of the stratum. The process was repeated 500 times, creating 500 new subsamples. Weights were recalculated for each of the 500 samples called the bootstrap weights. The bootstrap weights were used to calculate 500 estimates which are then used to estimate the variance.[171]

3.6.7 Statistical software

All statistical analyses were completed using SAS software version 9.4.[172]

Chapter 4

4 Results

This chapter will present the study findings. First, this chapter will summarize the missing data patterns for variables of interest. Then it will provide a description of the study sample. Following that, the results for objective 1, objective 2 and objective 3 will be presented.

4.1 Descriptive statistics

Of the CCHS respondents included in the study, 45.04% (150,305 respondents) were male and 54.96% (183,415 respondents) were female. Overall, 79% of respondents had complete data with no missing values for any of the variables included in this study. Table 4.1 outlines the missing data pattern for males and females. Percentage of missing values was generally low for most variables, with less than 1% missing. Income and fruit and vegetable consumption had the highest missing percentage; 8.77% and 9.67%, respectively, for males and 12.32% and 9.45%, respectively, for females. Missing patterns were similar between males and females except for BMI and smoking status. Female respondents had higher percentage of missing values for BMI compared to males (3.27% vs. 0.66%). Whereas men had higher percentage of missing values for the smoking variable (0.46% vs. 0.14%). When the descriptive statistics for the datasets with missing values and the imputed values are compared, the estimates are similar.

Table 4.1: Descriptive statistics for dataset with missing values

	Male (n = 150,305)			**Female (n = 183,415)**		
Variables	**Percent/ Mean(SD)**	**95% Confidence Interval**		**Percent/ Mean(SD)**	**95% Confidence Interval**	
Mode of interview						
Telephone	61.47	60.60	62.34	61.12	60.21	62.02
In person	38.53	37.66	39.40	38.88	37.98	39.79
	Percent missing = 0.10			Percent missing = 0.11		
Age	43.81 (16.42)	43.74	43.89	45.6 (17.26)	45.52	45.68
Visible minority						
White	80.53	80.01	81.04	80.96	80.52	81.40

Non-white	19.47	18.96	19.99	19.04	18.60	19.48
	Percent missing = 0.56			Percent missing = 0.49		
Marital status						
Not married	34.09	33.59	34.60	37.52	37.13	37.91
Married	65.91	65.40	66.41	62.48	62.09	62.87
	Percent missing = 0.10			Percent missing = 0.13		
Education						
Less than secondary school	14.60	14.32	14.87	14.46	14.21	14.71
Secondary school or more	85.40	85.13	85.68	85.54	85.29	85.79
	Percent missing = 1.08			Percent missing = 0.91		
Income						
No Income	0.34	0.27	0.40	0.27	0.22	0.31
Less than $5,000	0.51	0.45	0.58	0.57	0.52	0.62
$5,000 - $9,999	0.99	0.90	1.08	1.49	1.39	1.58
$10,000 - $14,999	2.37	2.24	2.50	4.26	4.12	4.41
$15,000 - $19,999	2.41	2.29	2.54	4.35	4.20	4.51
$20,000 - $29,999	6.91	6.69	7.14	9.66	9.42	9.89
$30,000 - $39,999	8.61	8.37	8.86	10.26	10.00	10.52
$40,000 - $49,999	8.89	8.63	9.14	9.45	9.21	9.69
$50,000 - $59,999	9.14	8.89	9.39	9.31	9.06	9.56
$60,000 - $79,999	17.53	17.15	17.90	16.49	16.15	16.83
$80,000 Or More	42.29	41.80	42.78	33.89	33.44	34.34
Mean Income	8.22 (2.13)	8.19	8.24	7.72 (2.31)	7.70	7.74
	Percent missing = 8.77			Percent missing = 12.32		
Household size						
1	12.07	11.57	12.58	14.50	14.01	14.96
2	32.80	32.20	33.39	33.65	33.04	34.18
3	19.49	19.10	19.88	18.47	18.08	18.83
4	21.73	21.14	22.32	20.16	19.67	20.61
5	9.16	8.79	9.52	8.89	8.51	9.25
6	4.75	4.43	5.08	4.44	4.16	4.71
Mean Household Size	2.97 (1.35)	2.94	3.01	2.89 (1.36)	2.86	2.91
Rurality						
Urban	82.06	81.70	82.42	82.93	82.61	83.25
Rural	17.94	17.58	18.30	17.07	16.75	17.39
BMI	26.37 (4.42)	26.34	26.41	25.06 (5.20)	25.02	25.10
	Percent missing = 0.66			Percent missing = 3.27		
Self-reported health						
Poor	9.48	9.23	9.72	11.19	10.92	11.46
Good	90.52	90.28	90.77	88.81	88.54	89.08

	Percent missing = 0.07			Percent missing = 0.08		
Having a regular doctor						
No	16.16	15.83	16.48	8.42	8.20	8.65
Yes	83.84	83.52	84.17	91.58	91.35	91.80
	Percent missing = 0.05			Percent missing = 0.03		
Visit doctor in past 12 months						
No	27.07	26.66	27.47	14.67	14.37	14.97
Yes	72.93	72.53	73.35	85.33	85.03	85.63
	Percent missing = 0.21			Percent missing = 0.42		
Alcohol drinking						
Currently non-drinker	14.35	14.01	14.69	22.88	22.48	23.28
Currently drinker	85.65	85.31	86.00	77.12	76.72	77.52
	Percent missing = 0.46			Percent missing = 0.42		
Smoking tobacco						
Currently non-smoker	73.65	73.24	74.06	79.47	79.16	79.79
Currently smoker	26.35	25.94	26.76	20.53	20.21	20.84
	Percent missing = 0.46			Percent missing = 0.14		
Physical Activity	2.31 (2.44)	2.28	2.33	1.94 (1.94)	1.93	1.96
	Percent missing = 0.13			Percent missing = 0.08		
Fruit and vegetable consumption	4.43 (2.55)	4.40	4.45	5.11 (2.64)	5.08	5.13
	Percent missing = 9.67			Percent missing = 9.45		

Note: Proportion and confidence interval are presented for categorical variables: mode of interview, visible minority, marital status, education, income, household size, rurality, self-reported health, having a regular doctor, visiting doctor in past 12 months, alcohol drinking and smoking tobacco. Mean and standard deviation (SD) with corresponding confidence intervals are presented for continuous variables: age, income, household size, BMI, physical activity, and fruits and vegetable consumption.

Table 4.2 summarizes the descriptive statistics for the imputed data. The mean age was 43.81 (SD=16.42) and 45.60 (SD=17.26) for males and females, respectively. Approximately 19% of males and females reported being visible minority, 65.90% of males and 62.47% of females reported being married, and approximately 14.60% of males and 14.46% of females reported having less than secondary schooling. A higher percentage of men reported an income of $80,000 or more compared to women (41.34% vs. 32.52). The mean income for men ($50,000-$79,999) was higher than women ($40,000-$59,999). Household size was similarly distributed between men and women with majority of household comprising of 1 to 4 people. The majority of people lived in urban centers (~82%).

Upon examining the health-related predictors, the mean BMI reported by men was 26.37 (SD=4.42). The mean BMI reported by women was slightly lower at 25.08 (SD=5.20). For self-report health, 9.48% of men and a slightly higher percentage of women (11.20%) reported having poor health.

For the behavioural predictors, 83.84% of men and 91.58% of women reported having regular doctors, and 72.99% of men and 85.10% of women reported visiting a doctor in the past 12 months. A higher percentage of men reported being current drinkers compared to women (85.62% vs. 77.70%). Additionally, a higher percentage of men reported being current smokers compared to women (26.34 vs. 20.53). Men had higher levels of physical activity compared to women; mean MET for men was 2.31 (SD=2.44), whereas, mean MET for women was 1.95 (SD=2.04). Lastly, women reported a higher percentage of fruit and vegetable consumption; mean fruit and vegetable consumption for females was 5.11 (SD=2.57) and mean fruit and vegetable consumption for men was 4.43 (SD=2.28).

Table 4.2: Descriptive statistics for dataset with imputed values

	Male (n = 150,305)			**Female (n = 183,415)**		
Variables	**Percent/ Mean(SD)**	**95% Confidence Interval**		**Percent/ Mean(SD)**	**95% Confidence Interval**	
Mode of Interview						
Telephone	61.48	60.61	62.35	61.12	60.22	62.03
In person	38.52	37.65	39.39	38.88	37.97	39.78
Age	43.81 (16.42)	43.74	43.89	45.60 (17.26)	45.52	45.68
Visible minority						
White	80.53	80.02	81.04	80.97	80.53	81.40
Non-white	19.47	18.96	19.98	19.03	18.60	19.47
Marital status						
Not married	34.10	33.60	34.60	37.53	37.14	37.91
Married	65.90	65.40	66.40	62.47	62.09	62.86
Education						
Less than secondary school	14.66	14.38	14.93	14.53	14.28	14.78
Secondary school or more	85.34	85.07	85.62	85.47	85.22	85.72
Income						

No Income	0.31	0.25	0.36	0.26	0.22	0.30
Less Than $5,000	0.49	0.43	0.55	0.57	0.53	0.62
$5,000 - $9,999	0.97	0.90	1.05	1.53	1.45	1.62
$10,000 - $14,999	2.45	2.34	2.56	4.42	4.29	4.55
$15,000 - $19,999	2.54	2.43	2.65	4.50	4.37	4.64
$20,000 - $29,999	7.14	6.93	7.34	10.02	9.82	10.22
$30,000 - $39,999	8.87	8.65	9.09	10.62	10.40	10.84
$40,000 - $49,999	9.05	8.83	9.27	9.70	9.49	9.90
$50,000 - $59,999	9.30	9.08	9.52	9.44	9.23	9.66
$60,000 - $79,999	17.55	17.21	17.88	16.41	16.11	16.71
$80,000 Or More	41.34	40.89	41.79	32.52	32.13	32.90
Mean Income	8.18 (2.17)	8.17	8.19	7.66 (2.36)	7.64	7.68
Household size						
1	12.07	11.57	12.58	14.48	14.01	14.96
2	32.80	32.20	33.39	33.61	33.04	34.18
3	19.49	19.10	19.88	18.45	18.08	18.83
4	21.73	21.14	22.32	20.14	19.67	20.61
5	9.16	8.79	9.52	8.88	8.51	9.25
6	4.75	4.43	5.08	4.43	4.16	4.71
Mean Household size	2.98 (1.35)	2.95	3.01	2.89 (1.36)	2.86	2.92
Rurality						
Urban	82.06	81.70	82.42	82.93	82.61	83.25
Rural	17.94	17.58	18.30	17.07	16.75	17.39
BMI	26.37 (4.42)	26.34	26.41	25.08 (5.20)	25.04	25.12
Self-reported health						
Poor	9.48	9.23	9.73	11.20	10.93	11.47
Good	90.52	90.27	90.77	88.80	88.53	89.07
Having a regular doctor						
No	16.16	15.84	16.48	8.42	8.20	8.65
Yes	83.84	83.52	84.16	91.58	91.35	91.80
Visit doctor in past 12 months						
No	27.01	26.60	27.42	14.60	14.30	14.90
Yes	72.99	72.58	73.40	85.40	85.10	85.70
Alcohol drinking						
Currently non-drinker	14.38	14.04	14.72	22.90	22.50	23.30
Currently drinker	85.62	85.28	85.96	77.10	76.70	77.50
Smoking						
Currently non-smoker	73.66	73.25	74.06	79.47	79.16	79.79
Currently smoker	26.34	25.94	26.75	20.53	20.21	20.84
Physical activity	2.31 (2.44)	2.28	2.33	1.95 (2.04)	1.93	1.96

Fruit and vegetable consumption	4.43 (2.48)	4.40	4.45	5.11 (2.57)	5.08	5.13

Note: Proportion and confidence interval are presented for categorical variables: mode of interview, visible minority, marital status, education, income, household size, rurality, self-reported health, having a regular doctor, visiting doctor in past 12 months, alcohol drinking and smoking. Mean and standard deviation (SD) with corresponding confidence intervals are presented for continuous variables: age, income, household size, BMI, physical activity, and fruits and vegetable consumption.

4.2 Objective 1

Among Canadian adults with unreported T2D, 0.56% (95% CI=0.49%, 0.63%) of men and 0.44% (95% CI=0.39%, 0.48%) of women experienced a hospitalization event related to T2D during 2000-2009. That is 840 men and 800 women who were hospitalized for T2D up to three years following the CCHS interview but reported no previous diagnosis of diabetes. The percentage hospitalization event related to T2D was higher among men than in women.

Table 4.3: Percentage of type 2 diabetes related hospitalization among adults with unreported diabetes

	Male (n = 150,305)			**Female (n = 183,415)**		
T2D related hospitalization	**Percent**	**95% Confidence Interval**		**Percent**	**95% Confidence Interval**	
No	99.44	99.37	99.51	99.56	99.52	99.61
Yes	0.56	0.49	0.63	0.44	0.39	0.48

4.3 Objective 2

Among Canadian adults with unreported T2D, 0.44% (95% CI=0.27%, 0.55%) of men and 0.33% (95% CI=0.23%, 0.43%) of women experienced a hospitalization event related to T2D in 2000. Among men, an increase in the percentage of T2D related hospitalizations was observed in 2001 (0.47%; 95% CI=0.36%, 0.59%). Hospitalizations declined in 2003 to 0.43% (95% CI=0.34%, 0.50%); however, the percentage of men experiencing T2D related hospitalization steadily increased after that: 0.49% (95% CI=0.57%, 0.99%) in 2005; 0.55% (95% CI=0.42%, 0.67%) in 2007; 0.65% (95% CI=0.42%, 0.88%) in 2008; 0.77% (95% CI=0.54%, 0.99%) in 2009. In contrast, among women, an increase in the percentage of T2D related hospitalization was observed till 2005 (0.52%; 95% CI=0.42%, 0.63%). However, the percentage declines to 0.37% (95%

CI=0.27%, 0.47%) in 2007. A further increase was observed after that: 0.40% (95% CI=0.25%, 0.50%) in 2008; 0.55% (95% CI=0.41%, 0.68%) in 2009. (Table 4.4)

Table 4.4: Temporal trend in percentage of type 2 diabetes related hospitalization between 2000 to 2009 among adults with unreported type 2 diabetes

	Male (n = 150305)			Female (n = 183415)		
Year of Interview	**Percent**	**95% Confidence Interval**		**Percent**	**95% Confidence Interval**	
2000	0.41	0.27	0.55	0.33	0.23	0.43
2001	0.47	0.36	0.59	0.37	0.28	0.45
2003	0.43	0.34	0.50	0.42	0.33	0.49
2005	0.49	0.40	0.57	0.52	0.42	0.63
2007	0.55	0.42	0.67	0.37	0.27	0.47
2008	0.65	0.42	0.88	0.40	0.28	0.50
2009	0.77	0.54	0.99	0.55	0.41	0.68

Figure 4.1 and Figure 4.2 illustrate the change in percentage of T2D related hospitalization among men and women with unreported T2D, respectively. The linear trend was tested and showed that men had higher odds of T2D related hospitalization between 2000 and 2009 (OR=1.07, CI=1.03, 1.12). This annual positive trend was a statistically significant (p=0.0004). For women, however, the linear trend in T2D related hospitalization was not statistically significant (p=0.0987; OR=1.03, CI=0.99, 1.06). Refer to Table 4.5 for the results of the linear trend test using logistic regression.

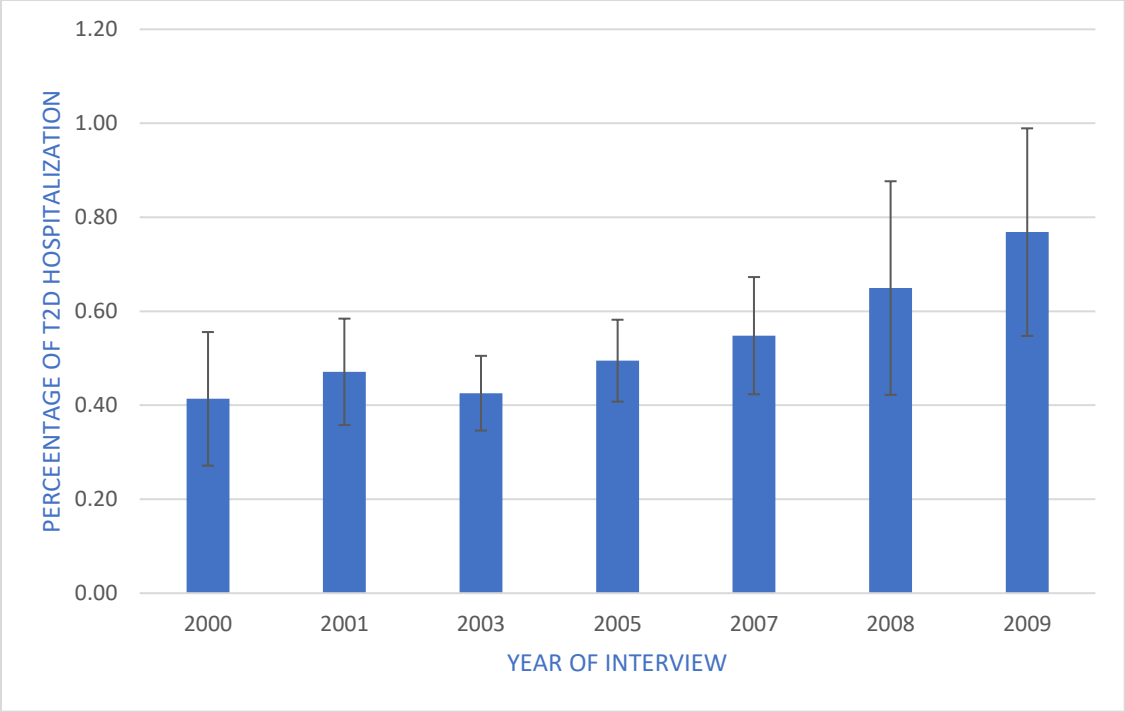


Figure 4.1: Temporal trends in percentage of type 2 diabetes related hospitalization between 2000 to 2009 among males with unreported type 2 diabetes

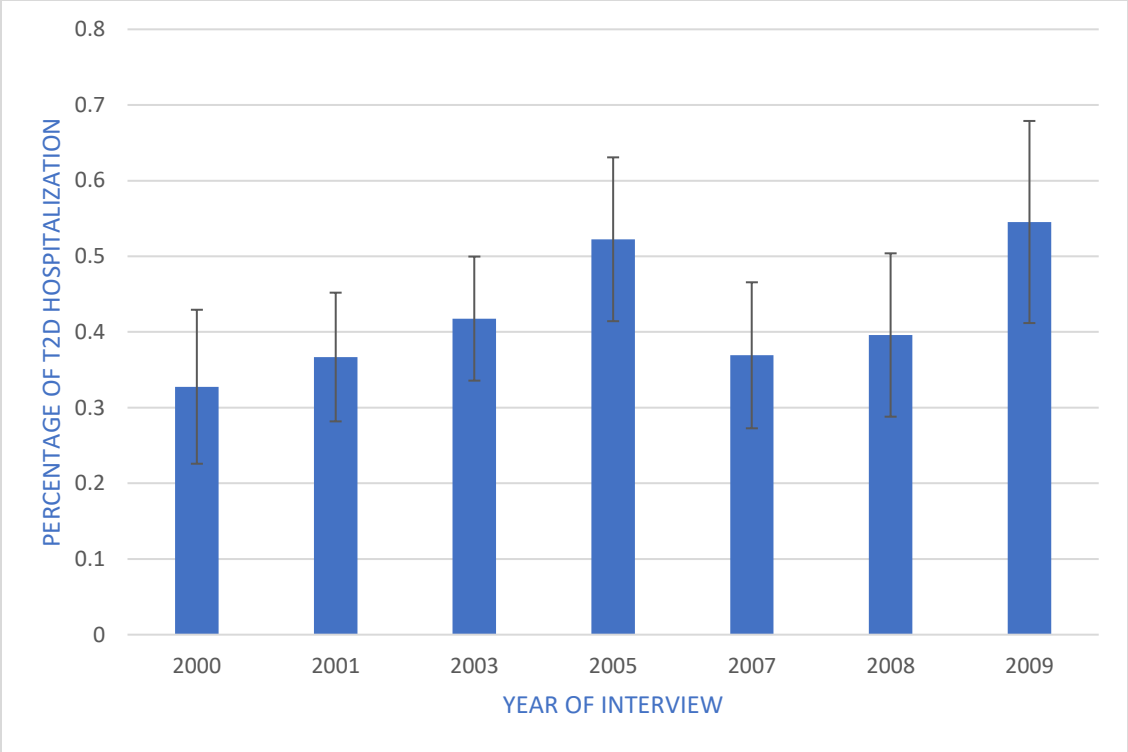


Figure 4.2: Temporal trends in percentage of type 2 diabetes related hospitalization between 2000 to 2009 among females with unreported diabetes

Table 4.5: Test of linear trend for type 2 diabetes related hospitalization between 2000 to 2009 among adults with unreported type 2 diabetes

	Male (n = 150305)				Female (n = 183415)			
Effect	**Odds ratio**	**95% Confidence interval**		**p-value**	**Odds ratio**	**95% Confidence interval**		**p-value**
Date of Interview	1.07	1.03	1.12	0.0004*	1.03	0.99	1.06	0.0987

Note: * denotes significances at alpha=0.05

4.4 Objective 3

Examination of the cross tabulation of sociodemographic, health-related, and behavioural predictors (see Table 4.6) reveals that a higher percentage of white males (0.59%, 95% CI= 0.53%, 0.66%) and white females (0.46%, 95% CI= 0.41%, 0.51%) with unreported T2D were hospitalized for T2D between 2000 to 2009 compared to non-white males and females (0.59%, 95% CI= 0.53%, 0.66% and 0.59%, 95% CI= 0.53%, 0.66%,

respectively). A higher percentage of married men reported T2D related hospitalization compared to non-married men (0.42%, 95% CI= 0.36%, 0.49% and 0.63%, 95% CI= 0.54%, 0.72%, respectively). In contrast, women who were not married reported a higher percentage of T2D related hospitalization compared to married women (0.53%, 95% CI= 0.46%, 0.60% and 0.38%, 95% CI= 0.33%, 0.43%, respectively). Both men and women who had less than secondary education reported higher percentage of T2D related hospitalization (1.13%, 95% CI= 0.97%, 1.29% and 1.09%, 95% CI= 0.93%, 1.24%, respectively) compared to men and women who had secondary school or more (0.46%, 95% CI= 0.39%, 0.53% and 0.32%, 95% CI= 0.28%, 0.36%, respectively). Both men and women who lived in a rural area reported higher percentage of T2D related hospitalization (0.53%, 95% CI= 0.46%, 0.61% and 0.41%, 95% CI= 0.37%, 0.46%, respectively) compared to men and women who lived in urban area (0.67%, 95% CI= 0.55%, 0.79% and 0.55%, 95% CI= 0.45%, 0.64%, respectively). Men and women who reported poor health reported much higher percentage of T2D related hospitalizations (1.95%, 95% CI= 1.67%, 1.24% and 1.28%, 95% CI= 1.10%, 1.47%, respectively) compared to men and women who reported good health (0.41%, 95% CI= 0.35%, 0.48% and 0.33%, 95% CI= 0.29%, 0.37%, respectively). Furthermore, both men and women who reported having a regular doctor reported a higher percentage of T2D related hospitalizations (0.63%, 95% CI= 0.56%, 0.71% and 0.46%, 95% CI= 0.41%, 0.50%, respectively) compared to men and women who did not have a regular medical doctor (0.17%, 95% CI= 0.12%, 0.23% and 0.21%, 95% CI= 0.13%, 0.30%, respectively). Additionally, both men and women who reported visiting a doctor in the past 12 months reported a higher percentage of T2D related hospitalizations (0.63%, 95% CI= 0.59%, 0.77% and 0.45%, 95% CI= 0.40%, 0.49%, respectively) compared to men and women who did not visit a doctor in past 12 months (0.23%, 95% CI= 0.17%, 0.30% and 0.37%, 95% CI= 0.27%, 0.47%, respectively). Both male and female current non-drinkers reported higher T2D related hospitalizations (0.95%, 95% CI= 0.76%, 1.14% and 0.84%, 95% CI= 0.71%, 0.97%, respectively) compared to current drinkers (0.49%, 95% CI= 0.43%, 0.56% and 0.31%, 95% CI= 0.28%, 0.35%, respectively). Lastly, men who are currently non-smokers reported a higher percentage of hospitalizations compared to current smokers (0.62%, 95% CI= 0.53%, 0.70% and 0.39%, 95% CI= 0.32%, 0.47%,

respectively). For women, the percentage of T2D related hospitalization reported for current smokers and non-smokers was the approximately the same (0.44%, 95% CI= 0.35%, 0.52% and 0.43%, 95% CI= 0.39%, 0.48%, respectively).

With respect to continuous predictors, the mean age for individuals with a T2D related hospitalization was 63.24 (SD=11.54) for men and 64.23 (SD=12.79) for women. This was higher than the average age of non-hospitalized respondents: 43.70 (SD=16.39) and 45.52 (SD=17.25) for men and women, respectively. The hospitalized group had a lower mean income category (7.2 [SD=1.96] for men, 6.14 [SD=1.98] for women) compared to non-hospitalized respondents (8.18 [SD=2.17] for men, 7.66 [SD=2.36] for women). Mean household size for non-hospitalized respondents was slightly higher (2.98 [SD=1.35] for men, 2.89 [SD=1.36] for women) compared to the hospitalized group (2.27 [SD=0.90] for men, and 2.1 [SD=0.90] for women). Both men and women had a higher mean BMI in the hospitalized group (28.86 [SD=4.41] and 28.77 [SD=5.91], respectively) compared to the non-hospitalized respondents (26.36 [SD=2.49] and 25.07 [SD=5.18], respectively). For men, the mean MET was 1.65 (SD=1.67) in the hospitalized group, whereas it was 2.31 (SD=2.44) in the non-hospitalized respondents. For women, the mean MET was 1.16 (SD=1.21) in the hospitalized group while it was 1.95 (SD=2.04) in the non-hospitalized respondents. Lastly, men in the hospitalized group reported slightly higher mean fruit and vegetable consumption (4.66 [SD=2.04]) compared to the non-hospitalized respondents (4.43 [SD=2.49]). In contrast, women in the hospitalized group reported slightly lower mean fruit and vegetable consumption (4.93 [SD=2.10]) compared to non-hospitalized respondents (5.11 [SD=2.57]).

Table 4.6: Cross tabulation of sociodemographic, health-related, and behavioural predictors and type 2 diabetes related hospitalization among adults with unreported type 2 diabetes

	Male (n = 150,305)			**Female (n = 183,415)**		
Variables	**T2D related hospitalization (n = 840)**			**T2D related hospitalization (n = 800)**		
	Percent	**95% Confidence Interval**		**Percent**	**95% Confidence Interval**	
Mode of Interview						
Telephone	0.48	0.43	0.54	0.42	0.37	0.47

In person	0.68	0.53	0.82	0.46	0.39	0.53
Age	63.24 (11.54)	61.84	64.63	64.23 (12.79)	62.66	65.80
Visible minority						
White	0.59	0.53	0.66	0.46	0.41	0.51
Non-white	0.41	0.20	0.62	0.32	0.22	0.42
Marital status						
Not married	0.42	0.36	0.49	0.53	0.46	0.60
Married	0.63	0.54	0.72	0.38	0.33	0.43
Education						
Less than secondary school	1.13	0.97	1.29	1.09	0.93	1.24
Secondary school or more	0.46	0.39	0.53	0.32	0.28	0.36
Income	7.20 (1.96)	6.99	7.42	6.14 (1.98)	5.93	6.35
Household size	2.27 (0.90)	2.14	2.41	2.1 (0.90)	1.97	2.22
Rurality						
Urban	0.53	0.46	0.61	0.41	0.37	0.46
Rural	0.67	0.55	0.79	0.55	0.45	0.64
BMI	28.86 (4.41)	28.33	29.40	28.77 (5.91)	28.07	29.47
Self-reported health						
Poor	1.95	1.67	2.24	1.28	1.10	1.47
Good	0.41	0.35	0.48	0.33	0.29	0.37
Having a regular doctor						
No	0.17	0.12	0.23	0.21	0.13	0.30
Yes	0.63	0.56	0.71	0.46	0.41	0.50
Visit doctor in past 12 months						
No	0.23	0.17	0.30	0.37	0.27	0.47
Yes	0.68	0.59	0.77	0.45	0.40	0.49
Alcohol Drinking						
Currently non-drinker	0.95	0.76	1.14	0.84	0.71	0.97
Currently drinker	0.49	0.43	0.56	0.31	0.28	0.35
Smoking tobacco						
Currently non-smoker	0.62	0.53	0.70	0.43	0.39	0.48
Currently smoker	0.39	0.32	0.47	0.44	0.35	0.52
Physical Activity	1.65 (1.67)	1.26	2.04	1.16 (1.21)	1.03	1.29
Fruit and vegetable consumption	4.66 (2.04)	4.27	5.06	4.93 (2.10)	4.71	5.15

Note: Proportion and confidence interval are presented for categorical variables: mode of interview, visible minority, marital status, education, rurality, self-reported health, having a regular doctor, visiting doctor in past 12 months, alcohol drinking and smoking tobacco. Mean and standard deviation (SD) with corresponding confidence intervals are presented for continuous variables: age, income, household size,

BMI, physical activity, and fruits and vegetable consumption. Income and household size frequencies distribution table were restricted outside RDC use due to low cell count in some categories.

Examination of the results from the multivariate logistic regression revealed year of interview, age, age^2, BMI, self-reported health, and having a regular doctor were statistically significant predictors of T2D related hospitalizations among men with unreported T2D. Similarly, age, BMI and self-reported health were statistically significant predictors of T2D related hospitalization among women with unreported T2D. In contrast, for women, year of interview, age^2 and having a regular doctor were not significant predictors of T2D related hospitalization, however, alcohol drinking, smoking tobacco, and physical activity were significant predictors of T2D related hospitalization .

For men, year of interview remained significant after controlling for other covariates (OR=1.07, 95% CI=1.03, 1.11). Examination of age revealed that in men, T2D related hospitalization increased until 55 years of age, after which, T2D related hospitalizations declined. Men also experienced higher odds of T2D related hospitalization with higher BMI (OR=1.07, 95% CI=1.06, 1.09). Men who reported poor health had higher odds of T2D related hospitalizations (OR=2.14, 95% CI=1.77, 2.58). Furthermore, having a regular doctor increased the odds of T2D related hospitalization in men (OR=1.56, 95% CI=1.07, 2.26).

For women, an increased odds of T2D hospitalization was observed until age 91, after which, T2D related hospitalization declined. The quadratic term however was not statistically significant in women. Among women, an increase in BMI was associated with higher odds of T2D related hospitalization (OR=1.08, 95% CI=1.07, 1.10). Those who reported poor health experienced higher odds of T2D related hospitalizations (OR=1.64, 95% CI=1.31, 2.05). Additionally, women who were current drinkers had lower odds of T2D related hospitalization (OR=0.67, 95% CI=0.53, 0.84). Those women who were current smokers had higher odds of T2D related hospitalizations (OR=1.56, 95% CI=1.21, 2.00). Lastly, a higher level of physical activity was associated with lower odds of hospitalization among women (OR=0.90, 95% CI=0.84, 0.97).

Table 4.7: Association between sociodemographic, health-related and behavioural predictors and type 2 diabetes related hospitalization among adults with unreported type 2 diabetes

	Male (n = 150,305)				Female (n = 183,415)			
Variables	**Odds Ratio**	**95% Confidence Interval**		**P-Value**	**Odds Ratio**	**95% Confidence Interval**		**P-Value**
Year of Interview	1.07	1.03	1.11	0.0005*	1.03	1.00	1.07	0.059
Mode of Interview	1.14	0.88	1.49	0.3138	0.88	0.72	1.07	0.1945
Age	4.08	2.85	5.85	<.0001*	2.28	1.54	3.38	<.0001*
Age^2	0.91	0.87	0.94	<.0001*	0.96	0.92	1.00	0.0776
Visible minority	1.22	0.72	2.06	0.4640	1.25	0.88	1.79	0.2183
Marital status	0.93	0.71	1.21	0.5722	1.06	0.78	1.44	0.7183
Education	0.92	0.74	1.15	0.4797	0.88	0.71	1.09	0.2465
Income	0.96	0.91	1.01	0.1025	0.94	0.89	1.00	0.0548
Household size	0.91	0.78	1.06	0.2256	0.91	0.77	1.07	0.2457
Rurality	1.01	0.8	1.28	0.9466	1.15	0.93	1.42	0.2032
BMI	1.07	1.06	1.09	<.0001*	1.08	1.07	1.10	<.0001*
Self-reported health	2.14	1.77	2.58	<.0001*	1.64	1.31	2.05	<.0001*
Having a regular doctor	1.56	1.07	2.26	0.0196*	1.42	0.91	2.22	0.126
Visit doctor in past 12 months	1.40	0.98	1.99	0.0642	0.88	0.65	1.19	0.4042
Alcohol drinking	0.83	0.65	1.05	0.1173	0.67	0.53	0.84	0.0006*
Smoking tobacco	1.02	0.80	1.3	0.875	1.56	1.21	2.00	0.0006*
Physical activity	0.95	0.83	1.08	0.4132	0.90	0.84	0.97	0.0049*
Fruit and vegetable consumption	1.03	0.98	1.08	0.2699	0.99	0.95	1.04	0.7183

Note: * denotes statistical significance at alpha=0.05

Chapter 5

5 Discussion

This chapter will summarize the results of each objective of this study and attempt to explain the findings. This chapter further lists the study strengths and limitations. Lastly, this chapter will discuss the potential future directions and implications of this research followed by a brief conclusion.

5.1 Key Findings

Between 2000 to 2009 among Canadian adults with unreported T2D, a higher percentage of males compared to females experienced a T2D related hospitalization. In those with unreported T2D, the percentage of T2D related hospitalization in men increased linearly from 2000 to 2009. The percentage of T2D-related hospitalizations among women with unreported T2D did not change from 2000 to 2009.

The results from the adjusted multivariate logistic regression revealed that year of interview, age, BMI, self-reported poor health and having a regular doctor were statistically significant predictors of T2D related hospitalizations in men who reported no previous T2D diagnosis. Similarly, increasing age, higher BMI and self-reported poor health also were significant predictors of T2D related hospitalization in women who reported no previous T2D diagnosis. Furthermore, alcohol drinking, smoking tobacco, and physical activity were also predictors of T2D related hospitalization in women who reported no previous T2D diagnosis.

5.2 Percentage of type 2 diabetes related hospitalization

The percentage of men with unreported T2D who experienced a T2D related hospitalization was higher than women between 2000 to 2009 (0.56% vs. 0.44%, respectively). Past literature has shown that T2D rates are higher among men compared to women, with men having 16% higher rates.[33] Men are also at risk for developing T2D at a lower BMI compared to women, which may explain why T2D is more common among men.[173] This may be because men are more likely to deposit fat in the

abdominal region, whereas women are more likely to deposit fat subcutaneously and on their lower extremities.[174] Adipose tissue in the abdominal region has been associated with increased health risks, including T2D.[174]

The percentage of T2D related hospitalizations also increased linearly with time for men but there was a not significant upward trend observed for women. There is research to suggest that BMI has increased globally since 1980.[175] In Canada, 68% of men and 54% of women were estimated to be overweight or obese.[176] Additionally, between 1985 and 2011, the prevalence of obesity increased from 6.1% to 18.3%. Increases in BMI might lead to an increase in newly diagnosed cases of T2D,[177] as obesity is a significant risk factor for T2D development. Adults with a BMI of 40 or higher are 7.37 times more likely to be diagnosed with T2D.[50] The increase in BMI may explain the increase in T2D hospitalization among unreported T2D individuals from 2000 to 2009.

5.3 Predictors of type 2 diabetes related hospitalization

5.3.1 Sociodemographic predictors

The findings from the current study show that CCHS respondents who reported no previous T2D diagnoses and experienced T2D related hospitalization were, on average, older than those who were not hospitalized. The adjusted multivariate logistic model showed that among men, T2D related hospitalization increased until 55 years of age and then decreased after that. Previous literature has shown that T2D related hospitalization varies by age. A CIHI report indicated a rise in T2D preventable hospitalization event until 40-59 years of age followed by a decreased observed from 60-74 years of age.[33] In contrast, another study involving First Nations adults concluded that total hospitalization among T2D patients decreases until 60 years of age and then increases after that.[122] The reason for this pattern may be that those at risk of developing T2D do so by 40-59 years of age. After that, the development of T2D might decline, as those who are at risk or predisposed to developing T2D might have developed it already.[173,178] The adjusted multivariate logistic model showed that among women, T2D related hospitalization increased until 91 years of age and then decreased after that; however, the quadratic term was not significant. According to a systematic review, more women are

overweight or obese after the age of 45 years, whereas more males are overweight at a younger age.[178] Women might develop T2D at an older age, which may explain why T2D hospitalizations do not show a significant decline in women with increasing age. Lastly, previous literature suggests that men are diagnosed with T2D at a lower BMI than women.[173] Therefore, T2D hospitalization events might be occur at a younger age in men and decline after that.

The results of this study showed that individuals in the white ethnic group reported a higher percentage of T2D hospitalization. This was true for both men and women. Furthermore, men who reported being married reported higher T2D related hospitalization, while women who reported being married reported lower T2D related hospitalization. In the adjusted multivariate logistic model, neither visible minority nor marital status were statistically significant predictors of T2D related hospitalization. Previous literature observed similar results; those who were married were less likely to have a T2D related hospitalization event, but this was not significant after controlling for confounders.[118] A Canadian study found that First Nations adults had almost four times the odds of having a hospitalization or emergency department visit for a T2D related events.[122] The rate of preventable hospitalizations among urban Métis adults was found to be twice that of non-Indigenous adults.[126] However, the visible minority variable used in this study was a binary variable (*white/non-white*) where the *non-white* comprise of a mix of all ethnic groups. Not all ethnic groups share the same risk of T2D and hospitalization risk. The effect of certain ethnic groups on hospitalization risk might have diminished the effects of others. For example, immigrants from the Caribbean, Europe and East Asia have been found to have lower odds of preventable hospitalization and the effect may be transgenerational.[179]

Among men and women, a higher percentage of T2D related hospitalization were reported among individuals with less than secondary schooling. Additionally, a lower average mean income was reported for the T2D related hospitalization group. In the adjusted multivariate logistic model, neither income nor education were statistically significant for men or women; household size was controlled to standardize the household income per individuals. These finding are in contrast to other studies. Findings

from one study suggests that the effect of education is not significant after controlling for income, which usually is a significant predictor of T2D related hospitalization.[118] Another study, by Chen et al., found socioeconomic effects of higher education as well as individual income were important factors which affect disparities in T2D related hospitalization.[119] However, in the study by Chen et al., education was recorded at the community level and they did not look at behavioural predictors.[119] Booth and Hux found an inverse gradient between income level and T2D hospitalizations.[120] However, Booth and Hux did not control for behavioural factors, and more importantly, individual income was estimated from neighborhood income which may lead to misclassification.[120] In the current study, there was not a significant effect of income on T2D related hospitalization. This may suggest that universal care may be succeeding in removing disparities associated with education and income. Additionally, income might not be reliably reported in the CCHS dataset. For instance, income variable was imputed due to 8.77% and 12.32% of the values missing for men and women.

Lastly, respondents who lived in rural areas were more likely to report hospitalization for T2D, however in the adjusted multivariate logistic model, this variable was not significant for males or females. In contrast, other studies have shown hospitalization rates were 60% higher in rural areas compared to urban areas.[33] An Ontario study found that more remote northern areas had higher rates of admission for hypoglycemia and emergency department visits for T2D between 1994 through 1999; but these areas experienced comparable or even greater declines in admission for hypoglycemia and emergency department visits for T2D compared to areas in southern Ontario.[44] This could indicate that efforts to mitigate the effects of accessibility in rural areas has been successful. Furthermore, residence of rural areas are more likely to be obese or overweight compared to urban dwellers.[180] After adjusting for BMI, the effects of rurality might diminish.

5.3.2 Health-related predictors

On average, men and women hospitalized for T2D had higher BMI. Both men and women who self-reported poor health also reported higher T2D related hospitalizations. In the adjusted multivariate logistic model, both BMI and self-reported poor health were

significant predictors of T2D related hospitalization for both men and women. Similar to previous studies, adults with overweight and obesity tend to have increased incidence of both general hospitalization and preventable hospitalization.[118,124] Furthermore, T2D can be accompanied by several other health conditions and worse health status is a predictor of hospitalization.[123] Previous studies have shown that having comorbidities with T2D increases the odds of hospitalization; with one comorbidity having higher odds of hospitalization compared to no comorbidity, and two or more comorbidities having even higher odds of hospitalization.[119] Obesity in people with T2D is associated with poor control of blood sugar, blood pressure and cholesterol levels; many of the health complications of T2D become more severe when they are compounded by overweight or obesity.[50–52] These contributing factors indicate why increased hospitalizations occurred among respondents with higher BMI.

5.3.3 Behavioural predictors

The results showed that individuals who reported having a regular doctor and visiting a doctor in the past 12 months also reported a higher percentage of T2D related hospitalization among men and women. The adjusted multivariate logistic model revealed that visiting a doctor in the past 12 months was not a significant predictor of hospitalization in either men or women. However, having a regular doctor was significantly associated with increased odds of hospitalization, but only for men. The potential reasons for observing these results may be that a higher percentage of men who have worse health seek to or are encouraged to have a regular doctor. Whereas women, who are generally more health conscious,[181,182] might see their regular doctor before their health worsens.

Previous literature reveals an equal percentage of hospitalization among those who consulted a doctor in past 12 months and those who did not.[123] A different study showed that, at an aggregated level, the average annual number of doctor visits per person had a U-shaped association with hospitalizations for all conditions combined. Specifically for patients with T2D, ischemic heart disease or renal disease, the lowest number of hospitalizations were found when there was 20 to 30 doctor visits a year.[183] A study from Alberta, Canada found that limited or increased use of primary care among

T2D patients was associated with increased risk of a subsequent hospitalization.[128] Those who visited primary care too much or too little were more likely to be hospitalized.[128] Higher use of primary care services may indicate worse health. Also, not using primary care services can lead to worsening of T2D related complications.[128] These studies suggest that the relationship between the number of consultations with doctor and hospitalizations might not be a linear relationship. In this study, the variable indicating the number of visits to a doctor was a binary variable and a linear relationship was not tested.

Among men, current non-drinkers and current non-smokers reported a higher percentage of T2D hospitalizations. Among women, current drinkers and non-drinkers reported a similar percentage of T2D related hospitalizations. In the adjusted multivariate logistic model, smoking tobacco and alcohol drinking status was not a significant predictor of T2D related hospitalization among men. In contrast, smoking tobacco and alcohol drinking were significant predictors of T2D hospitalization among women. These results align with previous Canadian literature which suggests that smoking is a risk factor for hospitalization, whereas occasional/moderate alcohol drinking is a protective factor against hospitalization.[123] Conflicting results come from some studies that aggregated the results for men and women; for example, smoking status and alcohol consumption were not related to T2D hospitalization.[118,184] However, this study examined these predictors separately for men and women and it was found that alcohol drinking, smoking tobacco and physical activity are significant predictors in women alone. Moderate alcohol consumption has been shown to lower the risk of T2D. A systematic review found that alcohol intake below 63 g/day played a protective role against T2D, with risk increasing above that threshold.[66] However, reductions in risk appeared to be specific to women, who exhibit a decreased risk of T2D.[66] A possible explanation for the sex differences could be that men more frequently drink heavily compared to women.[185] Another systematic review and meta-analysis showed moderate alcohol consumption might improve insulin sensitivity among women.[186] Both former and current smoking has been independently associated with a higher risk of incident T2D in men and women.[187] Also, the smoking variable used in this study was a binary variable indicating current smoking status. The reference group, current non-smokers, might have

been contaminated with less healthy former smokers. This contamination might be higher for men than women.

Lastly, results of this study show that men and women hospitalized for T2D had, on average, a lower volume of physical activity measured in MET and less fruit and vegetable consumption. In the adjusted multivariate logistic model, fruit and vegetable consumption was not a significant predictor of T2D hospitalization for men or women. Additionally, physical activity was not a significant predictor of T2D hospitalization for men, however, it was a significant predictor for women. Previous literature has shown that increased levels of physical activity can reduce preventable hospitalization in both men and women.[118] There is strong evidence for an inverse association between physical activity and risk of T2D, which may partly be mediated by reduced adiposity.[71] Modifiable behaviours, which are correlated with one another, might also have a greater influence on women. Other health behaviours such as increasing the amount of green leafy vegetables in an individual's diet has been shown to help reduce the risk of T2D.[67,68] Habitual consumption of sugar sweetened beverages has been shown to be associated with a greater incidence of T2D, independently of adiposity.[69] Furthermore, meat consumption has shown to increase risk of T2D.[70] However, the current study only measured fruit and vegetable consumption and did not control for other food groups which might mitigate the effects of increased fruit and vegetable consumption.

5.4 Strengths and Limitations

This study has both strengths and limitations. To our knowledge, this is the first Canadian study to examine T2D related hospitalizations among patients with unreported T2D. Also, this is the first Canadian study to look at temporal trends in T2D related hospitalization among patients with unreported T2D. A major strength of this study is that hospitalization data was used from hospitals across Canada, except Quebec. This comprehensive data source represented ~75% of all hospital separations in Canada and maintained standards for quality and consistency.[136] Additionally, the CCHS provides a rich source of information on self-reported health status and determinants of health, but lacks the details needed to study hospitalization events.[136] Linking the DAD with the

CCHS helped generate a better understanding about what brings Canadians in contact with acute care facilitates.[136] As a result of the large sample size, this study was able to analyze a number of sociodemographic, health-related and behavioural predictors of T2D related hospitalization.

One of the more significant limitations of this study was the self-reported T2D indicator from the CCHS. In order for a person to self-report having diabetes, they must recognize the term diabetes, have some knowledge of the disease, and associate the term with themselves.[188] However, not all CCHS respondents who may have been diagnosed with T2D will self-report that they have the disease. Respondents may not self-report having T2D for the following reasons: they do not understand the term; they might have never have been informed about the diagnosis; they have been informed of the diagnosis but they may disagree with the diagnosis; they may believe, since they are managing their condition, that the disease is cured; they may be aware and informed of T2D but are hiding the diagnosis because of stigma.[188] A Canadian study in Ontario examined the proportion of individuals with physician diagnosed T2D who reported having diabetes in population health survey in 2001. They found that only 75% of people with physician diagnosed T2D reported having the disease.[188] Additionally, respondents who did not self-report their T2D status were more likely to be women, live in urban areas, and have a shorter T2D disease duration.[188] Respondents who did not report their T2D status were less likely to require hospital care for hyperglycaemia.[188]

Self-reported data might also have been subject to social desirability bias or recall bias. For example, CCHS respondents might answer questions regarding health behaviours more positively because they believe it to be more socially acceptable.[189] Additionally, respondents might not remember accurately the answer to variables, such as fruit and vegetable consumption.

This study employed a three-year follow-up period. We anticipated that if a CCHS respondent reported no diagnosis of T2D at the time of their CCHS interview and was hospitalized within three years for a T2D related condition, it is likely they had undiagnosed T2D when the CCHS interview was conducted. However, individual may

have seen a doctor or taken lab tests diagnosing them with diabetes during this follow-up period. In which case, they would not be considered undiagnosed at the time of hospitalization.

Non-response to the CCHS might have biased the results of this study, as well. The CCHS response rate ranged from 69.8% to 78.9%.[137] The characteristics of those who agreed to participate in the CCHS might be different than those who did not agree to participate. Furthermore, 84.7% of those who completed the CCHS interview further agreed to share their data for linkage.[151] The CCHS might also underestimate T2D related hospitalizations due to selection bias. For instance, excluded from the CCHS are: persons living on reserves and other Aboriginal settlements, full-time members of the Canadian Forces, and institutionalized population.[137] The excluded population might possess different characteristics compared to the included population. For example, people living on reserves might have a higher T2D related hospitalizations.

Another limitation of this study is that this thesis did not utilized laboratory data or physician billing to confirm T2D diagnosis and investigate clinical predictors of T2D related hospitalizations. Furthermore, a qualitative study found that variables such as extreme social vulnerability (such as homeless, poverty and no social support), health system interaction issues (such as poor communication with providers), limited health-related knowledge, behavioural health issues (such as substance abuse and mental illness), denial of illness and practical problems (such as being too busy) were some of the reasons listed for T2D related hospitalizations.[190] This study did not control for these factors, which might lead to residual confounding. Other important factors such as comorbidity was also not controlled for; which has also been linked to elevating diabetes hospitalizations.[191]

The DAD might also underestimate T2D related diagnosis. A Spanish study examined a cohort of 1036 patients admitted to a hospital over a seven-day period. They found 178 patients had T2D; 15% of admitted patients had previously diagnosed and 1.9% had been newly diagnosed. Out of the 178 T2D cases, 144 were recorded in the discharge record, that is 19% of T2D cases were not reported in administrative datasets.[192] Other studies

have also shown under-reporting of T2D cases in a hospital setting.[31,193,194] Therefore, the true incidence of T2D hospitalization among self-reported undiagnosed diabetes might be underestimated.

The variable utilized to represent the construct of income had limitations as well. First, the income variable was not standardized to geographic differences in cost of living. Secondly, the income categories representing low-high income on a scale of 0-10 remained constant over the CCHS cohorts used in this study. This is problematic as low-high income cutoffs change over place and time. Although the CCHS over the years has developed income variables that are standardized to account for variability over place and time, these variables were not available in the early years of the survey and were not available for the Canadian territories.

Lastly, poor measurement of constructs such as alcohol drinking, fruits and vegetable consumption, BMI can create bias which can distort study results. For example, CCHS participants were asked to recall if they drank in the past year, however, this did not include how much alcohol was consumed. Excessive drinking might pose a larger problem than drinking frequency.[195] Another poor measurement of construct might have been fruits and vegetable consumption. CCHS respondents were asked to recall the frequency of fruits and vegetable consumption. However, this may be subject to recall bias. Furthermore, measurement of other unhealthy food choices was not assessed. Lastly, studies have shown that measurements such as waist circumference and waist to hit ratio are slightly better at predicting diabetes and diabetes complications in both sexes compared to BMI.[196,197]

5.5 Implications and further direction

In direct response to the potential limitations of the present study, it is of interest to utilize more reliable methods of ascertaining undiagnosed T2D and T2D related hospitalizations. Ensuring health administrative dataset are capturing diagnosis accurately and using clinical data, such as laboratory tests, to ascertain outcome.

The results of this thesis align with previous literature suggesting T2D prevalence tends to be higher in men,[33] and men also develop T2D at a lower BMI compared to women.[173] Similarly, undiagnosed T2D is higher in men compared to women.[79,80] Practical implications of this finding can include health care providers being aware of the higher risk of T2D incidence among men. Higher incidence of T2D in men can lead to higher rates of T2D cases going undiagnosed. Therefore, theoretically, screening in men should occur at a lower BMI compared to women. Previous literature has examined why men experience higher rates of T2D compared to women and suggests that adipose tissue is associated with increased risk of T2D and men are more likely to deposit fat in the abdominal region compared to women.[174] However, there is no consensus on why men experience higher rates of T2D compared to women. Future research should focus on the causal pathway of T2D and how this differs between genders, including non-binary groups.

Percentage of T2D related hospitalization among unreported T2D patients increased from the period 2000-2009. Research suggests an increase in overweight and obesity in Canada, more so in men than in women.[176] Increases in BMI might lead to an increase in newly diagnosed cases of T2D.[177] This should raise the alarm for policy makers and health care providers as with increasing economic costs, diagnosing T2D at an early stage is key to affording the opportunity to treat T2D, and T2D control is key to reducing the risk of complications. Future research should assess reasons for the rise in T2D related hospitalization among undiagnosed T2D Canadians, given that crude T2D related are decreasing.

In the US, there is evidence to suggest that undiagnosed T2D crude prevalence increased during the past two decades but has decreased over time as a proportion of total T2D cases.[90] Although there is literature in Canada that aims to estimate the prevalence of undiagnosed T2D, there is a lack of literature on temporal trends in crude undiagnosed T2D prevalence in the Canadian context. Due to the lack of Canadian literature on national trends in crude undiagnosed T2D prevalence, the rise in T2D related hospitalization among undiagnosed T2D Canadian cannot directly be compared. Future

research should concentrate on examining national trends in crude undiagnosed T2D prevalence.

The results from the adjusted multivariate logistic regression revealed that age, BMI, self-reported health and having a regular doctor were statistically significant predictors of T2D related hospitalizations in Canadian adults. Whereas, visible minority, income and rurality were not significant predictors of T2D related hospitalization. These findings are in contrast to other studies on ethnicity,[122,126,179] income,[118–120] and rurality.[33] Modifiable health behaviours such as drinking alcohol, smoking tobacco and physical activity were associated with T2D related hospitalization among women. The practical implications of these finding are that modifiable health behaviours can aid in creating a healthier society and these modifiable health behaviours might be more important in women's health. This thesis could not explain why males and females differed in their predictors for T2D related hospitalization. Future research should aim to explore the sex differences observed in T2D related hospitalization for modifiable health behaviours.

While much research focuses on predictors of T2D related hospitalization among people with T2D in Canada, more research needs to focus on understanding the determinants of T2D related hospitalization among people with undiagnosed T2D and how they are associated with experiencing undiagnosed T2D and subsequent preventable hospitalization. This thesis was not able to examine clinical predictors, such FPG levels, which have been previously associated with increased T2D hospitalization risk.[114] With plans for linkage projects involving the CCHS and the CIHI datasets in the future, research should examine clinical predictors, as well as controlling for a plethora of other confounders of T2D related hospitalization.

5.6 Conclusion

Between 2000 and 2009, a higher percentage of males compared to females with unreported T2D experienced a T2D related hospitalization event. Identifying undiagnosed diabetes could be an effective strategy to minimize the long-term impacts of the disease. Screening intervention could permit timely initiation of therapy designed to prevent or delay the occurrence of complications. Additionally, this thesis examined the temporal

trends in T2D related hospitalization among individuals with unreported T2D. The percentage of T2D related hospitalizations among men with unreported T2D increased linearly from 2000 to 2009. With the rise in T2D related hospitalizations among individuals with unreported T2D, potentially due to increased prevalence of obesity and newly, policymakers should address this issue.

Lastly, this thesis explored potential sociodemographic, health-related and behavioural predictors of T2D related hospitalization among individuals with undiagnosed T2D. The adjusted multivariate logistic regression revealed that age, BMI, self-reported health were significant predictors of T2D related hospitalizations in men and women. However, alcohol drinking, smoking tobacco, and physical activity were significant predictors of T2D related hospitalization in women only. Modifiable health behaviours might have a greater influence on women. While the current analysis was not able to ascertain causality, future research should focus on understanding these relationships. Future research should also focus on linking other administrative datasets, such as physician billing or laboratory results, to ascertain T2D diagnosis status. Furthermore, identifying undiagnosed T2D could be an effective strategy to minimize the long-term impacts of the disease.

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Appendices

Appendix A: Description of ICD-10 codes and their corresponding ICD-9 codes

ICD-10-CA	Description	ICD-9	Description
E1100	TYPE 2 DIABETES MELLITUS WITH HYPEROSMOLARITY WITHOUT NONKETOTIC HYPERGLYCEMIC-HYPEROSMOLAR COMA (NKHHC)	25020	DIABETES MELLITUS WITH HYPEROSMOLARITY TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
		25022	DIABETES MELLITUS WITH HYPEROSMOLARITY TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
E1101	TYPE 2 DIABETES MELLITUS WITH HYPEROSMOLARITY WITH COMA	25020	DIABETES MELLITUS WITH HYPEROSMOLARITY TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
		25032	DIABETES MELLITUS WITH OTHER COMA TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
E1121	TYPE 2 DIABETES MELLITUS WITH DIABETIC NEPHROPATHY	25042	DIABETES MELLITUS WITH RENAL MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
E1129	TYPE 2 DIABETES MELLITUS WITH OTHER DIABETIC KIDNEY COMPLICATION	25040	DIABETES MELLITUS WITH RENAL MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
E11311	TYPE 2 DIABETES MELLITUS WITH UNSPECIFIED DIABETIC RETINOPATHY WITH MACULAR EDEMA	25050	DIABETES MELLITUS WITH OPHTHALMIC MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
		25052	DIABETES MELLITUS WITH OPHTHALMIC MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
		36207	DIABETIC MACULAR EDEMA
E11319	TYPE 2 DIABETES MELLITUS WITH	25050	DIABETES MELLITUS WITH OPHTHALMIC MANIFESTATIONS

	UNSPECIFIED DIABETIC RETINOPATHY WITHOUT MACULAR EDEMA		TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
		25052	DIABETES MELLITUS WITH OPHTHALMIC MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
		36201	BACKGROUND DIABETIC RETINOPATHY
E11329	TYPE 2 DIABETES MELLITUS WITH MILD NONPROLIFERATIVE DIABETIC RETINOPATHY WITHOUT MACULAR EDEMA	36203	NONPROLIFERATIVE DIABETIC RETINOPATHY NOS
		36204	MILD NONPROLIFERATIVE DIABETIC RETINOPATHY
E11339	TYPE 2 DIABETES MELLITUS WITH MODERATE NONPROLIFERATIVE DIABETIC RETINOPATHY WITHOUT MACULAR EDEMA	36205	MODERATE NONPROLIFERATIVE DIABETIC RETINOPATHY
E11349	TYPE 2 DIABETES MELLITUS WITH SEVERE NONPROLIFERATIVE DIABETIC RETINOPATHY WITHOUT MACULAR EDEMA	36206	SEVERE NONPROLIFERATIVE DIABETIC RETINOPATHY
E11359	TYPE 2 DIABETES MELLITUS WITH PROLIFERATIVE DIABETIC RETINOPATHY WITHOUT MACULAR EDEMA	36202	PROLIFERATIVE DIABETIC RETINOPATHY
E1136	TYPE 2 DIABETES MELLITUS WITH DIABETIC CATARACT	25050	DIABETES MELLITUS WITH OPHTHALMIC MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
		25052	DIABETES MELLITUS WITH OPHTHALMIC MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
		36641	DIABETIC CATARACT

E1139	TYPE 2 DIABETES MELLITUS WITH OTHER DIABETIC OPHTHALMIC COMPLICATION	25050	DIABETES MELLITUS WITH OPHTHALMIC MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
		25052	DIABETES MELLITUS WITH OPHTHALMIC MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
E1140	TYPE 2 DIABETES MELLITUS WITH DIABETIC NEUROPATHY, UNSPECIFIED	25060	DIABETES MELLITUS WITH NEUROLOGICAL MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
		25062	DIABETES MELLITUS WITH NEUROLOGICAL MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
E1142	TYPE 2 DIABETES MELLITUS WITH DIABETIC POLYNEUROPATHY	3572	POLYNEUROPATHY IN DIABETES
E1151	TYPE 2 DIABETES MELLITUS WITH DIABETIC PERIPHERAL ANGIOPATHY WITHOUT GANGRENE	25070	DIABETES MELLITUS WITH PERIPHERAL CIRCULATORY DISORDERS TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
		25072	DIABETES MELLITUS WITH PERIPHERAL CIRCULATORY DISORDERS TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
E11618	TYPE 2 DIABETES MELLITUS WITH OTHER DIABETIC ARTHROPATHY	25080	DIABETES MELLITUS WITH OTHER SPECIFIED MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
E11620	TYPE 2 DIABETES MELLITUS WITH DIABETIC DERMATITIS	25080	DIABETES MELLITUS WITH OTHER SPECIFIED MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
E11621	TYPE 2 DIABETES MELLITUS WITH FOOT ULCER	25080	DIABETES MELLITUS WITH OTHER SPECIFIED MANIFESTATIONS TYPE II OR

			UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
E11622	TYPE 2 DIABETES MELLITUS WITH OTHER SKIN ULCER	25080	DIABETES MELLITUS WITH OTHER SPECIFIED MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
E11628	TYPE 2 DIABETES MELLITUS WITH OTHER SKIN COMPLICATIONS	25080	DIABETES MELLITUS WITH OTHER SPECIFIED MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
E11630	TYPE 2 DIABETES MELLITUS WITH PERIODONTAL DISEASE	25080	DIABETES MELLITUS WITH OTHER SPECIFIED MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
E11638	TYPE 2 DIABETES MELLITUS WITH OTHER ORAL COMPLICATIONS	25080	DIABETES MELLITUS WITH OTHER SPECIFIED MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
E11641	TYPE 2 DIABETES MELLITUS WITH HYPOGLYCEMIA WITH COMA	25030	DIABETES MELLITUS WITH OTHER COMA TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
E11649	TYPE 2 DIABETES MELLITUS WITH HYPOGLYCEMIA WITHOUT COMA	25080	DIABETES MELLITUS WITH OTHER SPECIFIED MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
E1165	TYPE 2 DIABETES MELLITUS WITH HYPERGLYCEMIA	25002	DIABETES MELLITUS WITHOUT COMPLICATION TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
		25012	DIABETES MELLITUS WITH KETOACIDOSIS TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
		25022	DIABETES MELLITUS WITH HYPEROSMOLARITY TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
		25032	DIABETES MELLITUS WITH OTHER COMA TYPE II OR

			UNSPECIFIED TYPE UNCONTROLLED
		25042	DIABETES MELLITUS WITH RENAL MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
		25052	DIABETES MELLITUS WITH OPHTHALMIC MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
		25062	DIABETES MELLITUS WITH NEUROLOGICAL MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
		25072	DIABETES MELLITUS WITH PERIPHERAL CIRCULATORY DISORDERS TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
		25080	DIABETES MELLITUS WITH OTHER SPECIFIED MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
		25082	DIABETES MELLITUS WITH OTHER SPECIFIED MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
		25092	DIABETES MELLITUS WITH UNSPECIFIED COMPLICATION TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
E1169	TYPE 2 DIABETES MELLITUS WITH OTHER SPECIFIED COMPLICATION	25010	DIABETES MELLITUS WITH KETOACIDOSIS TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
		25012	DIABETES MELLITUS WITH KETOACIDOSIS TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
		25080	DIABETES MELLITUS WITH OTHER SPECIFIED MANIFESTATIONS TYPE II OR

			UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
		25082	DIABETES MELLITUS WITH OTHER SPECIFIED MANIFESTATIONS TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
E118	TYPE 2 DIABETES MELLITUS WITH UNSPECIFIED COMPLICATIONS	25090	DIABETES MELLITUS WITH UNSPECIFIED COMPLICATION TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED
		25092	DIABETES MELLITUS WITH UNSPECIFIED COMPLICATION TYPE II OR UNSPECIFIED TYPE UNCONTROLLED
E119	TYPE 2 DIABETES MELLITUS WITHOUT COMPLICATIONS	25000	DIABETES MELLITUS WITHOUT COMPLICATION TYPE II OR UNSPECIFIED TYPE NOT STATED AS UNCONTROLLED

Appendix B: Association between sociodemographic, health-related and behavioural predictors and type 2 diabetes related hospitalization among adults with unreported type 2 diabetes: Results from Unimputed dataset

Variables	Odds Ratio	95% Confidence Interval		P-Value	Odds Ratio	95% Confidence Interval		P-Value
Year of Interview	1.07	1.03	1.12	0.0007*	1.04	1.00	1.08	0.0348*
Type of Interview	1.15	0.85	1.56	0.3543	0.93	0.74	1.16	0.5145
Age	3.40	2.30	5.02	<.0001*	1.96	1.29	2.97	0.0018*
Age^2	0.93	0.89	0.97	0.0011*	0.98	0.94	1.02	0.316
Visible Minority	1.24	0.65	2.36	0.5157	1.63	1.11	2.41	0.0133*
Marital status	0.89	0.66	1.21	0.4713	1.33	0.95	1.86	0.1023
Education	0.94	0.73	1.20	0.5988	0.92	0.72	1.19	0.5345
Income	0.96	0.91	1.01	0.1047	0.93	0.87	1.00	0.0481*
Household size	0.90	0.76	1.07	0.2199	0.76	0.64	0.90	0.0021*
Rurality	1.08	0.82	1.42	0.6031	1.13	0.87	1.46	0.3805
BMI	1.07	1.05	1.09	<.0001*	1.09	1.07	1.10	<.0001*
Self-reported health	1.95	1.58	2.41	<.0001*	1.92	1.47	2.52	<.0001*
Having a regular doctor	1.68	1.12	2.52	0.0124*	1.53	0.89	2.64	0.1245
Visit doctor in past 12 months	1.52	1.02	2.27	0.0385*	0.81	0.55	1.20	0.2917
Alcohol drinking	1.00	0.77	1.31	0.9799	0.75	0.59	0.95	0.0164*
Smoking	1.06	0.81	1.38	0.6662	1.48	1.08	2.03	0.0143*
Physical activity	0.95	0.81	1.11	0.5095	0.88	0.80	0.96	0.0052*
Fruit and vegetable consumption	1.03	0.97	1.10	0.2937	1.01	0.96	1.05	0.8298

Curriculum Vitae

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