FACTORS ASSOCIATED WITH GLYCEMIC CONTROL, HOSPITALIZATION, AND MORTALITY AMONG NEWFOUNDLAND AND LABRADOR RESIDENTS WITH DIABETES MELLITUS

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Abstract

Diabetes is among the most prevalent chronic conditions in Canada. It is characterized by a body's inability to produce or efficiently use insulin. Diabetes can be effectively managed, often with the support of a primary care provider. Unfortunately, the high turnover rate of family physicians (FPs) in Newfoundland and Labrador (NL) threatens continuity of care, potentially contributing to poorer health outcomes for people with diabetes. This study examines the relationship between FP turnover and glycemic control, hospitalization, and mortality among patients with diabetes in NL. It was hypothesized that FP turnover would be related to the three outcomes of interest. Specifically, it was expected that high turnover rates would be associated with poorer glycemic control and increased risk of hospitalization and mortality. To examine these hypotheses, a cross-sectional analysis of adults (20+ years) with diabetes in NL between 2011 and 2015 was performed. Secondary data sources were linked, including the provincial Chronic Disease Registry and the Physician and Medical Practice Database. Multivariate binary logistic regression was used to examine the relationship between FP turnover, glycemic control, hospitalization, and mortality while controlling for important covariates. The analyses provided mixed support for the hypotheses. FP turnover was found to be associated with glycemic control and hospitalization but not mortality. Further, FP turnover was associated with an increased risk of hospitalization, but the direction of the relationship between turnover and glycemic control was inconsistent with the hypothesis. Findings from this study also suggest that regions with no FPs performed similarly to regions with low turnover on the outcomes of glycemic control and hospitalization. These findings may have implications for the delivery of primary care in

NL. Future studies should examine primary care models in regions with no FPs and consider whether these models could be more widely applied in NL for chronic disease management. Additionally, studies in other provinces should compare regions with high rates of primary care change (i.e., high turnover) to regions with consistent primary care availability to determine whether consistent primary care delivery, irrespective of the presence of FPs, is associated with better outcomes for patients with chronic condition.

General Summary

Diabetes is one of the most common chronic conditions in Canada. Most people with diabetes can live a healthy life and manage their disease. Diabetes management can include changes to lifestyle, medications, and self-management. The best course of diabetes management is usually supported by a primary care provider such as a family doctor. Access to a family doctor is important to patients with chronic conditions. Patients with chronic conditions are the most frequent users of primary care. Unfortunately, family doctors in Newfoundland and Labrador (NL) are leaving their positions (turning over) at one of the highest rates in the country. The turnover of family doctors may reduce the ability of patients to access health care and may contribute to poorer health outcomes. Within this thesis, the relationship between the turnover of family doctors and meaningful health outcomes for patients with diabetes was examined. The relationship between the turnover of family doctors and glycemic control (blood glucose management), hospitalization, and death among people with diabetes in NL was explored. It was expected that turnover would be related to glycemic control, hospitalization, and death. Specifically, it was expected that people living in places with higher turnover of family doctors would have poorer glycemic control and would be more likely to be hospitalized or die. To answer this question, secondary data from NL between the years 2011 and 2015 were analyzed. Turnover was found to be related to glycemic control and hospitalization but not death. Higher turnover was found to be related to a higher rate of hospitalization. The relationship between turnover and glycemic control was not clear. In contrast, results showed that people living in regions with no family doctors had similar outcomes to people living in regions with a low turnover rate. Future studies look at how

health care is delivered in regions of the province with no family doctors. These regions could offer evidence for the delivery of health care in other parts of NL. Additionally, it may be that consistency of primary care availability is an important contributor to patient outcomes and should be explored further.

Co-Authorship Statement

Richard Buote is the primary author of the work enclosed in this thesis. This thesis has been edited and reviewed by supervisors and committee members Dr. Maria Mathews, Dr. Julia Lukewich, Dr. John Knight, and Dr. James Valcour. Drs. Mathews, Lukewich and Knight were responsible for acquiring the data used in the study. Dr. Mathews and colleagues developed the turnover metric used in the study. At the time of submission of this thesis, this work had been presented at conferences but had not been published. Publication will be sought in relevant Canadian medical journals, such as CMAJ and CMAJ Open, and Canadian diabetes journals, such as the Canadian Journal of Diabetes.

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List of Acronyms

APP ..... Alternative payment plan

BMI ..... Body mass index

CA ..... Census agglomeration

CCDSS ..... Canadian Chronic Disease Surveillance System

CCHS ..... Canadian Community Health Survey

CIHI ..... Canadian Institute for Health Information

CIHR ..... Canadian Institute of Health Research

CMA ..... Census metropolitan area

COC ..... Continuity of care

CPG ..... Clinical practice guideline

FFS ..... Fee-for-service

FP ..... Family physician

FPG ..... Fasting plasma glucose

HbA_{1c} ..... Glycated hemoglobin

ICD ..... International Statistical Classification of Diseases and Related Health Problems

IDDM ..... Insulin dependent diabetes mellitus

IDF ..... International Diabetes Federation

LDL-C ..... Low-density lipoprotein cholesterol

MCP ..... Medical Care Plan

MIZ ..... Metropolitan influenced zones

MMCI ..... Modified modified care index

NIDDM ..... Non-insulin dependent diabetes mellitus

NL ..... Newfoundland and Labrador

NLCHI ..... Newfoundland and Labrador Centre for Health Information

PDAD ..... Provincial Discharge Abstract Database

SAC ..... Statistical area classification

SD ..... Standard deviation

SECON ..... Sequential continuity index

SES..... Socio-economic status

SPSS..... Statistical Package for the Social Sciences

T1DM..... Type 1 diabetes mellitus

T2DM..... Type 2 diabetes mellitus

UACR ..... Urine albumin-to-creatinine ratio

UPC..... Usual provider continuity

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Chapter 1: Introduction

1.1 Background

Chronic disease is a growing concern for the Canadian health care system. The average age of Canadians is increasing, resulting in a rising burden of chronic disease (Statistics Canada, 2017a). In the province of Newfoundland and Labrador (NL), this is of particular concern; NL has the oldest population in the country and some of the poorest modifiable health behaviours (Canadian Institute for Health Information, 2016; Statistics Canada, 2017a). These factors have contributed to more than half of the population of NL having one or more chronic disease (Government of Newfoundland and Labrador, 2015) and the prevalence of many chronic diseases, such as heart failure, cardiovascular disease, and diabetes, are among the highest in Canada (Public Health Agency of Canada, 2015a).

1.2 Diabetes Mellitus

Diabetes mellitus is a chronic metabolic condition characterized by an inability of one's body to produce or use insulin effectively (International Diabetes Federation, 2019; Punthakee et al., 2018). Without insulin, a person is unable to use and break down glucose, resulting in abnormally high blood sugar levels. If a patient has uncontrolled blood glucose levels for an extended period, they are at risk of developing complications. Typically, diabetes is classified as one of three types; type 1 diabetes mellitus (T1DM) (previously called insulin-dependent diabetes mellitus [IDDM] or juvenile diabetes), type 2 diabetes mellitus (T2DM) (previously called non-insulin-dependent diabetes mellitus [NIDDM] or adult-onset diabetes), and gestational diabetes. T2DM is the most common of these types, accounting for approximately 90% of diabetes prevalence in high-income countries, such as Canada (International Diabetes Federation, 2019). In Canada, in 2021,

the estimated prevalence of diabetes was about 3.4 million people or 10% of the Canadian population (Diabetes Canada, 2021a). In NL, in 2021, the estimated prevalence of diabetes was 70,000 people or 13% of the population (Diabetes Canada, 2021b).

Although diabetes itself negatively affects a person's health, individuals with the disease are also at a high risk of many complications and comorbidities. People with diabetes face an increased risk of cardiovascular disease (including heart attacks, stroke, heart failure), blindness, complications during pregnancy, poor oral health, and depression (Houlden, 2018; International Diabetes Federation, 2019). Those with diabetes are also at risk of nerve damage, most often in the lower limb (International Diabetes Federation, 2019), which can lead to injuries, infection, and amputation. Diabetes is the most common cause of non-traumatic lower limb amputation in high-income countries, including Canada (Houlden, 2018; International Diabetes Federation, 2019). Diabetes is also the leading cause of end-stage renal disease in high-income countries (Houlden, 2018; International Diabetes Federation, 2019). These various complications may result in early mortality for people with diabetes, often due to heart attack or stroke (International Diabetes Federation, 2019; Stone et al., 2018). The many complications and comorbidities of diabetes have created a substantial financial burden on the health care system. In 2020, the estimated direct cost of diabetes to the NL health care system was $67 million (Diabetes Canada, 2020b). As the prevalence of diabetes increases, so will the cost. It is expected that in the year 2030, the direct cost of diabetes to NL will be $79 million (Diabetes Canada, 2020b).

Although diabetes is associated with severe complications and comorbidities, it is often possible to manage diabetes through lifestyle and health care interventions.

Currently, around 80% of medical care for people with diabetes occurs in a primary care setting (Clement et al., 2018). Primary care is an element of primary health care that is often defined as first contact care that aims to prevent, diagnose, and treat injury and illness (Government of Canada, 2012). In NL, primary care is typically delivered by a family physician (FP). Primary care focuses on diagnoses and treatment, health promotion and education, and chronic disease prevention and management (Allen, 2010; Government of Canada, 2012). There is evidence that suggests diabetes is best managed within a primary care setting where the care is patient-centred, proactive, and delivered by an interprofessional team, resulting in fewer complications and hospitalizations (Clement et al., 2018; Dahrouge, 2012; O'Reilly et al., 2007; Worrall & Knight, 2011).

Continuity of care is an important component of primary care. For people with diabetes, good continuity of primary care with an FP is associated with higher patient satisfaction, better medication adherence, lower hospitalization rates, fewer emergency department visits, and lower mortality rates (C. C. Chen et al., 2013; Gulliford et al., 2007; Worrall & Knight, 2011). Unfortunately, NL has high turnover rates of FPs, which may threaten continuity of care, and lead to poorer health outcomes in people with diabetes and other chronic diseases in the province (Canadian Institute for Health Information, 2019; Mathews et al., 2008). NL relies on FPs for primary care delivery and has limited support of other primary care providers. NL has been slower to introduce primary care reforms to support the role of other providers within a primary care setting, such as nurses (Mathews et al., 2020), thus, the turnover of FPs is particularly harmful for patients in NL, as patients are reliant on FPs for primary care delivery.

1.3 Continuity of Care

Good continuity of care occurs when discrete health care events for an individual patient are delivered in a connected, coherent, and consistent way (Haggerty et al., 2003). Previous studies have established that good continuity of care results in better health and chronic disease outcomes (H. M. Chen et al., 2017; Knight et al., 2017; Worrall & Knight, 2011).

Haggerty and colleagues (2003) identify three types of continuity of care; informational, management, and relational. Informational continuity refers to information linking one health care provider or event to another. The information might be documented or exist in the memory of the provider. Management continuity refers to the organization of services, most often for those with long-term conditions, specifically, offering services in a complementary and consistent manner while remaining flexible to a patient's changing needs. Finally, relational continuity refers to the ongoing relationship between the patient and their health care provider(s). In primary care, continuity of care is typically understood as a longitudinal relationship between a patient and their physician (Haggerty et al., 2003). Relational continuity is central to high-quality primary care.

The personal relationship between a patient and their primary care physician has been posited to improve communication and trust and create a "sustained sense of responsibility" from the physician to their patient (Haggerty et al., 2003). Relational continuity is disrupted when an FP leaves a community and may result in decreased quality of care. Considering the importance of continuity of care for diabetes management and care, in this thesis, I examine how physician turnover affects those with diabetes using turnover as a proxy measure of continuity of care.

Typical measures of continuity of care use administrative data. A meta-analysis of continuity of care studies in Canada identified the continuity of care index as the most commonly used measure of continuity of care (Van Walraven et al., 2010). This measure operationalizes continuity of care as a percentage of visits by a single patient to the same provider(s) for a single illness episode (Bice & Boxerman, 1977). Other quantitative measures of continuity of care have been developed, typically assessing the concentration or dispersion of visits between a patient and their physician(s) (University of Manitoba, 2011; Van Walraven et al., 2010). These measures are useful when billing data are available. However, in regions of the country like NL, where such administrative data are unavailable for all patients, there is a need for an alternative measure of continuity of care.

Approximately 60-65% of physicians in NL are fee-for-service, while the remaining 35-40% are remunerated using some form of alternative payment plan (APP)[1] (Canadian Institute for Health Information, 2020a). Further, in NL, APP physicians are not required to shadow bill.[2] Therefore, administrative data are missing for a large proportion of the patient population in the province (Lix et al., 2012). Given that billing data are unavailable for many physicians, there is a need for an alternative method of assessing continuity of care in regions where fee-for-service billing data are unavailable. Physician turnover may act as a proxy measure for continuity of care and can be

[1] APP are payment plans other than FFS, including salary, block funding, capitation, or blended models. Salary and block funding are the predominant types of APP used in NL (Canadian Institute for Health Information, 2011).

[2] Physicians remunerated under alternative payment plans may be required to submit invoices, or shadow bill, for services provided. Physicians may receive minimal or no remuneration for this, but it creates a more complete administrative database (Canadian Institute for Health Information, 2015).

calculated using physician distribution data. The Institute of Clinical Evaluative Sciences developed a measure of physician turnover, or turnover index, to assess workforce stability (Tepper et al., 2006). Previous measurements of turnover and retention have provided counts of incoming and outgoing physicians, but the novelty of the turnover index is that it indicates whether the physicians attributed to a location are the same individual. When testing this measure in Ontario, physician turnover was highest in rural communities (Tepper et al., 2006). Similar studies in NL have also indicated that rural regions of the province struggle to retain physicians (Knight et al., 2017; Mathews et al., 2008). These findings suggest that patients in rural communities may experience poorer continuity of care due to high rates of physician turnover.

Two studies conducted in NL have examined the effect of continuity of care on outcomes for people with diabetes. Worrall and Knight (2011) examined how continuity of care affects older people with diabetes. This study found a relationship between higher continuity of care and lower hospitalization rates and death. However, a limitation of this study was the use of older data from only fee-for-service physicians. Knight and colleagues (2009) examined the effect of continuity of FP care on hospitalization among older people (65+ years) with diabetes in NL. This study found a significant association between higher levels of continuity of care and lower rates of hospitalization. Together, these two studies suggest that poor continuity of care can have a negative effect on patients with diabetes in NL but are limited by the use of administrative data, which do not include all patients in the province. One study in NL has tested physician retention as a proxy measure of continuity of care. Knight and colleagues (2017) examined the relationship between physician retention and avoidable hospital admissions. Retention

was calculated using data from a provincial physician database (i.e., the Physician and Medical Practice Database), which includes data on all physicians, regardless of payment method. Retention was defined as the "proportion of physicians practising in a given economic zone at the start of [a time period] who were still practising in that zone at the end of [a time period]" (Knight et al., 2017, p. 2). This study found that poor FP retention was related to high rates of hospital admission for ambulatory-care-sensitive conditions. This study from Knight and colleagues (2017) offers preliminary evidence that a turnover index, which is a complementary proportion of retention, can act as a proxy for continuity of care, but further research is needed to validate this measure.

1.5 Rationale

Although NL has the highest prevalence of diabetes in the country, there is a paucity of research on relationships between diabetes outcomes and the organization of health care within the province. To address this gap, the research conducted within this thesis examines how FP turnover affects those with diabetes. This project uses secondary data to explore this topic. It is among the first to use both the Physician and Medical Practice Database and Chronic Disease Registry in NL, offering novel insight into the broader population of people with diabetes in NL and the state of physician availability in the province, beyond fee-for-service physicians, by including FPs paid under an APP. The Chronic Disease Registry contains data on people with diabetes in NL and was linked with other secondary health databases, specifically, those containing laboratory and hospitalization data. These data sources were used within this study to understand the relationship between FP turnover in NL and important outcomes for patients with diabetes.

1.6 Research Questions

What factors are related to glycemic control, hospitalization, and mortality among patients with diabetes in Newfoundland and Labrador? Using Andersen and Newman's Behavioural Model of Health Services Utilization and secondary health and physician workforce data, this study examined the predisposing, enabling, and need factors associated with glycemic control, hospitalization, and mortality among patients with diabetes in NL.

1.6.1 Research Objectives

The objectives of this study are to understand what factors are predictive of glycemic control, hospitalization, and mortality among patients with diabetes in NL. Given that diabetes is typically managed in primary care, a specific aim of this project was to examine the relationship between FP turnover and health outcomes for patients with diabetes. Specifically, the primary objectives were to:

1) Examine differences in the likelihood of having glycemic control among people with diabetes who live in high, moderate, and low physician turnover areas, as well as regions with no FPs.
2) Examine differences in the likelihood of hospitalization among people with diabetes who live in high, moderate, and low physician turnover areas, as well as regions with no FPs.
3) Examine differences in the likelihood of mortality among people with diabetes who live in high, moderate, and low physician turnover areas, as well as regions with no FPs.

The secondary objective was to:

4) Explore the quality of diabetes care by examining whether people with diabetes who live in high, moderate, and low physician turnover areas, as well as regions with no FPs, received routine tests (glycated hemoglobin [HbA_{1c}], low-density lipoprotein cholesterol [LDL-C], and urine albumin-to-creatinine ratio [UACR]) according to diabetes management guidelines.

1.6.2 Hypotheses

I hypothesized that:

1) People with diabetes living in regions with no FPs or in regions with high FP turnover would be more likely to have poor glycemic control than those living in regions with low FP turnover.
2) People with diabetes living in regions with no FPs or in regions with high FP turnover would be more likely to be hospitalized than those living in regions with low FP turnover.
3) People with diabetes living in regions with no FPs or in regions with high FP turnover would be more likely to die than those living in regions with low FP turnover.
4) People with diabetes living in regions with no FPs or in regions with high FP turnover would be less likely to have routine tests than those living in regions with low FP turnover.

1.7 Implications

NL's current Chronic Disease Framework (Department of Health & Community Services, 2011) and Chronic Disease Action Plan (Division of Health and Community Service, 2017) recognize the growing challenge of chronic disease for the health care

system. These frameworks focus heavily on the need for improved chronic disease management in NL, specifically discussing the importance of self-management and telehealth, as well as the inclusion of nurses and allied health providers in chronic disease management. I have hypothesized that the high FP turnover will be associated with poorer health outcomes for patients with diabetes, thus, there is a need to examine how primary care is delivered in NL. The use of telehealth and the inclusion of other, non-physician providers within primary care in NL may help reduce the impact of FP turnover in NL by ensuring that patients have consistent access to primary care, irrespective of FP turnover. The results of this study will inform health policy reform provincially and nationally, improving primary care delivery for those with chronic disease.

Chapter 2: Literature Review

2.1 Organization of Literature Review

The primary focus of this thesis is to examine factors related to outcomes for patients with diabetes in Newfoundland and Labrador (NL). Specifically, this thesis examines the effect of family physician (FP) turnover on health-related outcomes for patients with type 1 and type 2 diabetes across the province. The two primary topics of this thesis are primary care and diabetes mellitus (hereafter diabetes). This literature review will begin with definitions and discussions of primary health care and primary care for the Canadian context. Next, diabetes will be discussed, including the incidence and prevalence of diabetes across Canada and in NL, as well as the etiology and pathophysiology of diabetes.

To examine whether FP turnover affects patients with diabetes in NL, Andersen and Newman's Behavioural Model of Health Services Utilization was applied. The authors of this framework posits that predisposing, enabling, and need factors can be used to explain and predict health service use (Andersen, 1995; Andersen & Newman, 2005). Predisposing factors refer to a person's demographics, social structure, and beliefs. Enabling factors include family variables (i.e., income and insurance coverage) and community variables (i.e., the ratio of health personnel to community population and price of health services in the community). Finally, need factors refer to both perceived need (i.e., how sick a person believes they are) and assessed need (i.e., illness level evaluated by a clinician). This model has been applied to many studies examining health care, most often where usual sources of care and evaluated health status are the focus (Babitsch et al., 2012). This framework was applied to guide variable operationalization,

data analyses, and interpretation of the results. Variables related to health services utilization among patients with diabetes will be identified and discussed within the following section.

2.2 Primary Health Care

The definition of primary health care can be ambiguous and often depends on the context to which it is being applied. In lower-income countries, primary health care is often defined as a system-wide strategy for public health, incorporating services necessary for the health of the population (Muldoon et al., 2006). The World Health Organization (WHO) describes primary health care using three main elements; empowered people and communities; multi-sectoral policy and action; and primary care and essential public health functions as the core of integrated health services (World Health Organization, 2000). Primary health care includes services provided by governments to promote and protect the health of their people, including, at a minimum, education, nutrition, safe water, adequate sanitation, maternal and child health, provision of essential drugs and immunizations, and prevention and treatment of local disease and ailments (Dukes, 1978; World Health Organization, 2000). Primary health care should include not only the health sector but also other national sectors, such as education, employment, housing, and agriculture. The goal of primary health care is to improve the health of all individuals in the country, specifically aiming to reduce health inequities.

Within Canada, the definition of primary health care is often based around the goal of primary health care but often focuses on the delivery of services and activities associated with primary health care. For example, Health Canada defines primary health care as "an approach to health and a spectrum of services beyond the traditional health

care system. It includes all services that play a part in health, such as income, housing, education, and environment" (Government of Canada, 2012, para. 1). The Canadian Institute for Health Information (CIHI) defines primary health care as "an important source of chronic disease prevention and management. It may involve health professionals such as nurses, nurse practitioners, physicians, dietitians, physiotherapists and social workers. This type of care typically involves routine care, care for urgent but minor or common health problems, mental health care, …, health promotion and disease prevention, …" (Canadian Institute for Health Information, 2016, para. 1). This definition from CIHI highlights key features of primary health care, namely the offering of services through an interprofessional team-based approach, organized in a way that can be responsive to the needs of the community (Government of Canada, 2012; Hutchison et al., 2011). Finally, Muldoon and colleagues (2006) state that the definition of primary health care should "describe an approach to health policy and service provision which includes both services delivered to individuals and population-level 'public health-type' functions and which derives from core principles articulated by the World Health Organization" (p. 411).

2.3 Primary Care

Primary care is a central component of primary health care where patients have their first contact with the health care system, typically through an FP (Canadian Institute for Health Information, 2016; Government of Canada, 2012). Primary care can be defined as the "level of a health service system that provides entry into the system for all new needs and problems, provides person-focused (not disease-oriented) care over time, provides care for all but very uncommon or unusual conditions, and coordinates or

integrates care provided elsewhere or by others" (Starfield, 1998, pp. 8–9). This definition includes the four central features of primary care; first contact access, continuity, comprehensiveness, and care coordination (Starfield, 1992). Although primary care is a component of primary health care, there is a distinction between the two concepts — primary health care, as a level of care, is broader, including all services that may impact the health of an individual. In contrast, primary care is more specific, encompassing the level of care where patients have their first contact with the health care system, often thought of as "family doctor-type" services (Government of Canada, 2012; Muldoon et al., 2006). For patients with chronic diseases, such as diabetes, most of their care takes place in primary care. In Canada, patients with diabetes receive 80% of their care in a primary care setting (Clement et al., 2018).

2.4 Diabetes Mellitus

Diabetes is a chronic metabolic condition characterized by an inability of one's body to produce or effectively use insulin (Punthakee et al., 2018). Without insulin, a person is unable to use and break down glucose, resulting in high blood glucose levels. Elevated blood glucose levels over an extended period can lead to various complications.

Diabetes is typically classified as one of three types; type 1 (T1DM) (previously insulin-dependent diabetes [IDDM] or juvenile diabetes), type 2 (T2DM) (previously non-insulin-dependent diabetes [NIDDM] or adult-onset diabetes), and gestational diabetes (Punthakee et al., 2018). A diagnosis of diabetes is made based on a person's level of glycemia (level of glucose in the blood) which is determined through blood glucose testing (Punthakee et al., 2018). The diagnostic threshold for a diagnosis of diabetes, according to the Diabetes Canada Clinical Practice Guidelines (Goldenberg &

Punthakee, 2013; Punthakee et al., 2018), are fasting plasma glucose (FPG) ≥7.0 mmol/L, two-hour plasma glucose of ≥ 11.1 mmol/L, random plasma glucose of ≥ 11.1 mmol/L, or glycated hemoglobin (HbA_{1c}) of ≥6.5%. These criteria were developed based on the risk of developing microvascular diseases, such as retinopathy (Punthakee et al., 2018). In addition to diagnosing cases of diabetes, HbA_{1c} is a strong predictor of cardiovascular complications (Imran et al., 2018). HbA_{1c} testing measures the amount of glucose attached to blood cells, which indicates the average glucose concentration within the blood over the previous eight to 12 weeks (Berard et al., 2018; Sacks, 2011). HbA_{1c} is a reliable measure of average blood glucose levels, and this testing is widely used because it can be performed at any time of day and does not require fasting, making it less burdensome for the patient (Berard et al., 2018; Sacks, 2011). Additionally, HbA_{1c} testing has lower variability within an individual, making the testing more reproducible than glucose testing (Sacks, 2011). The ability of HbA_{1c} testing to predict microvascular complications, lower patient burden, and higher reproducibility make it the standard for diabetes diagnosis and monitoring.

Typically, screening for diabetes focuses only on detecting cases of *type 2 diabetes* due to a lack of interventions that prevent or delay the onset of type 1 diabetes (Ekoe et al., 2018). Screening for type 2 diabetes typically involves blood glucose testing, and there is no distinction between screening and diagnostic testing. Diabetes Canada and the Canadian Task Force on Preventative Health Care (Ekoe et al., 2018; Sherifali et al., 2013) recommend that individuals at risk of developing type 2 diabetes (i.e., 40 years of age and older, first-degree relative with type 2 diabetes, member of a high-risk

population, such as Aboriginal, African, Arab, Asian descent, low socioeconomic status) are screened, at minimum, every three years. Although Diabetes Canada makes these recommendations, the grade of the evidence is relatively low (Grade D), as the effectiveness of screening for type 2 diabetes has not been well established (Ekoe et al., 2018; Sherifali et al., 2013).

In Canada, the incidence and prevalence of diabetes have been increasing with time (Lipscombe & Hux, 2007). Increasing rates may be attributable to low rates of physical activity, poor diet, and rising rates of obesity (Taylor, 2016; Twells et al., 2014). When examining increasing prevalence rates, although the growing incidence plays a role, patients with diabetes are living longer, resulting in a higher number of Canadians currently living with diabetes (Lipscombe & Hux, 2007; Public Health Agency of Canada, 2017). The improved lifespan of people with diabetes may be a result of improved screening and public awareness of diabetes, resulting in earlier diagnoses (Lipscombe & Hux, 2007).

Estimates of diabetes prevalence in Canada vary depending on the data source used. In 2019, the Canadian Community Health Survey (CCHS) estimated that 7.8% of Canadians over the age of 12 had diabetes. NL had a higher estimated prevalence at 10.6%. This estimate includes individuals who self-reported a diagnosis of type 1, type 2, or gestational diabetes. The CCHS provides the lowest estimated prevalence, which may be because of the self-reported nature of the survey; therefore, those who are unaware or who have not been informed of their diabetes status will not be represented in this estimate. The International Diabetes Federation (IDF; 2019) uses data from the Canadian Community Health Survey to estimate diabetes prevalence. IDF estimates that the

Canadian diabetes prevalence was 7.6% for the same period. The prevalence estimate from IDF is slightly lower because it only includes individuals aged 20-79 years, while the CCHS includes individuals aged 12 years and older. Another estimate of diabetes prevalence comes from the Canadian Chronic Disease Surveillance System (CCDSS). In 2016, the CCDSS estimated the age-standardized prevalence of diabetes in Canada to be 8.02% (Public Health Agency of Canada, 2019b). In NL, the prevalence was estimated to be 9.01% for the same year (Public Health Agency of Canada, 2019b). The CCDSS uses linked administrative data to determine diabetes incidence and prevalence (Public Health Agency of Canada, 2013). According to the CCDSS definition, a person is considered to have diabetes if they "have at least one hospitalization record or at least two physician claims in a two-year period with an ICD code for diabetes" (Public Health Agency of Canada, 2015, p. 3). Diabetes Canada has estimated diabetes prevalence using the Canadian Diabetes Cost Model, which projects diabetes prevalence in Canada to be around 10.0% (Diabetes Canada, 2021a). The Canadian Diabetes Cost Model uses national data from government sources to estimate incidence, prevalence, and economic burden (Diabetes Canada, 2021a).

The CCDSS is the only one of these sources to provide an annual estimate of diabetes incidence. For 2016, the CCDSS estimated the age-standardized incidence of diabetes in Canada to be 616 cases per 100,000 individuals and 699 cases per 100,000 individuals in NL (Public Health Agency of Canada, 2015a). Incidence is higher among males than females in both Canada (709 cases per 100,000 males and 534 cases per 100,000 females) and NL (772 cases per 100,000 males and 632 cases per 100,000 females) (Public Health Agency of Canada, 2019a). A Canadian report from 2003 using

data from the National Population Health Survey and the CCHS found that the incidence of diabetes from 1998/99 to 2000/01 was 6.7 per 1,000 individuals (Millar & Young, 2003).

2.4.1 Type 1 Diabetes Mellitus

T1DM is typically diagnosed among people under the age of 25 but is most often diagnosed in children aged 5-7 and those at or close to the age of puberty (Atkinson et al., 2014; Punthakee et al., 2018). It results from an auto-immune episode, as the immune system attacks and destroys insulin-producing beta cells within the pancreas, leaving it unable to produce insulin (Atkinson et al., 2014; International Diabetes Federation, 2019). As a result of this inability to produce insulin, those with T1DM require insulin therapy and would die without it. The prevalence of T1DM is much lower than T2DM, accounting for only around 10% of diabetes cases globally (International Diabetes Federation, 2019). Globally, European countries have the highest rates of T1DM, with Finland having the highest incidence of T1DM (>60 cases per 100 000 people each year) (Karvonen, 2006). In North America, Canada has the highest incidence of T1DM, affecting between 20.6-24.5/100 000 people annually (Karvonen, 2006), and the incidence of T1DM in NL is among the highest in the world (from 1987 to 2005, 35.08 cases per 100 000 people; Newhook et al., 2008)

Although currently T1DM is incurable, with good lifestyle (i.e., diet, exercise) and disease management (i.e., insulin use, blood glucose monitoring) those with T1DM can live a healthy life (International Diabetes Federation, 2019). Risk factors for developing T1DM include a family history of diabetes, genetics, infections, and other environmental influences (International Diabetes Federation, 2019). Although risk factors for the disease

have been identified, the exact causes of the disease are somewhat unclear. Numerous causes of T1DM have been explored, including diet at a young age, viruses, and environmental factors (Rewers & Ludvigsson, 2016). Furthermore, the incidence of T1DM has been increasing worldwide for several decades (Rewers & Ludvigsson, 2016). This increased incidence cannot be explained through genetics alone. Studies of genetically similar individuals have found differing rates of T1DM incidence, suggesting external factors play a central role in T1DM development (Kondrashova et al., 2005). Further research is needed to determine the mechanisms causing T1DM.

2.4.2 Type 2 Diabetes Mellitus

T2DM is the most common type of diabetes, accounting for around 90% of diabetes prevalence in high-income countries (International Diabetes Federation, 2019). T2DM can manifest in different ways. According to the Diabetes Canada Clinical Practice Guidelines, "[t]ype 2 diabetes may range from predominant insulin resistance with relative insulin deficiency to a predominant secretory defect with insulin resistance" (Punthakee et al., 2018, p. 1). According to this definition, T2DM causes both insulin resistance, that is, the resistance of a person's organs to the effect of insulin, and reduction in insulin secretion. Regardless of the mechanism, over time, insulin levels become insufficient, resulting in hyperglycemia (high levels of glucose in the blood). Symptoms include frequent urination, excessive thirst, weight change, and blurred vision (Diabetes Canada, 2019; International Diabetes Federation, 2019). T2DM can go undiagnosed for years, resulting in complications. There are an estimated 231.9 million cases of undiagnosed cases of diabetes globally (International Diabetes Federation, 2019). To

determine the prevalence of undiagnosed T2DM in Canada, Rosella and colleagues (2015) compared the prevalence of self-reported diabetes to blood glucose measures. They found that, depending on the method of blood glucose testing, the prevalence of undiagnosed T2DM in Canada was between 1.13-3.38%. These numbers suggest that there may be more than one million Canadians currently living with T2DM who are unaware of their status.

Risk factors for T2DM include an age of 40 years or older, having a first-degree relative with T2DM, ethnicity (e.g., African, Indigenous, South Asian), prediabetes, history of gestational diabetes, history of associated diseases (e.g., pancreatitis, polycystic ovary syndrome), abdominal obesity, overweight, smoking, hypertension, and low high-density lipoprotein cholesterol (<1.0 mmol/L in males, <1.3 mmol/L in females) (Ekoe et al., 2018; Punthakee et al., 2018).

2.4.3 Gestational Diabetes Mellitus

Gestational diabetes is a type of diabetes occurring among pregnant women without a previous diagnosis of diabetes but who develop elevated blood glucose levels during pregnancy (Canadian Diabetes Association, 2013; Feig et al., 2018). During pregnancy, a woman's body produces placental hormones, which help in the growth of the baby but can affect the mother's metabolism (Feig et al., 2018). Changing metabolism can result in high blood glucose levels and gestational diabetes. It is differentiated from other types of diabetes as it is a temporary condition that occurs during pregnancy (Canadian Diabetes Association, 2013). Although gestational diabetes is considered temporary, it is associated with an increased risk of T2DM to both the mother and child (Feig et al., 2018; Vounzoulaki et al., 2020).

2.4.4 Prediabetes

Prediabetes is a term used to refer to a person with an elevated blood glucose level but below the level required for a diagnosis of diabetes. Typically, a diagnosis of prediabetes means an individual has impaired glucose tolerance (two-hour plasma glucose in a 75-gram oral glucose tolerance test of 7.8–11.0 mmol/L), impaired fasting glucose (fasting plasma glucose of 6.1-6.9 mmol/L), or an HbA_{1c} level of 6.0%-6.4% (Punthakee et al., 2018), but questionnaires and body measurements may also be used to diagnose prediabetes (Tabák et al., 2012).

Prediabetes is not considered a "fixed state"; it is not a certainty that those with prediabetes will eventually develop T2DM (Punthakee et al., 2018). A person may reverse high blood glucose levels through lifestyle changes, such as improved diet and physical activity or pharmaceutical intervention (Tabák et al., 2012). Regardless, a recent systematic review found that patients with prediabetes are at an increased risk of cardiovascular events, coronary heart disease, stroke, and all-cause mortality (Y. Huang et al., 2016). Prescription drugs have been shown to reduce the incidence of T2DM among those at high risk, although, at this time, the use of pharmaceuticals to prevent the onset of T2DM is uncommon (Moin et al., 2015). Impaired glucose tolerance, impaired fasting glucose, and HbA_{1c} of 6.0-6.4% can be used to diagnose an individual with prediabetes. Because of these different diagnostic criteria for prediabetes (e.g., impaired fasting glucose, impaired glucose tolerance), conversion rates from prediabetes to T2DM are variable. Some studies have shown conversion rates from prediabetes to T2DM to be as high as 10% while others have shown rates to be as low as around 3.5% (Edelstein et al., 1997; Tabák et al., 2012), although one study suggested that lifetime incidence of

T2DM among individuals with prediabetes could be as high as 90% (Tabák et al., 2012). One factor contributing to the varying conversion rates from prediabetes to T2DM is the test and threshold level used to diagnose prediabetes and that there is no globally accepted definition of prediabetes (Punthakee et al., 2018). For example, Diabetes Canada uses an HbA_{1c} value of 6.0-6.4% to define prediabetes, while the American Diabetes Association uses 5.7-6.4%. Studies have found that the most reliable method of detecting cases of prediabetes that are likely to become T2DM is to use a combination of tests (Heianza et al., 2012). Heianza and colleagues (2012) compared the efficacy of different testing methods (HbA_{1c} and fasting plasma glucose [FPG]) and various thresholds on conversion rates from prediabetes to T2DM. This study found that individuals diagnosed with prediabetes using both HbA_{1c} and FPG tests were more likely to develop T2DM than those diagnosed by a single test result. For example, individuals with HbA_{1c} of 6.0-6.4% and fasting plasma glucose of 6.1-6.9 mmol/L had a 100% cumulative incidence of T2DM.[3]

Finally, the reproducibility of prediabetes testing can be poor. Studies have found that some glucose testing, such as the oral glucose tolerance test, can have high levels of variation within the same individual (Balion et al., 2007; Ko et al., 1998; Simon et al., 1999). One systematic review found that the reproducibility of prediabetes testing was 49%, which was lower than the reproducibility of T2DM (73%) and normoglycemia (identifying blood glucose levels in the normal range) testing (93%) (Balion et al., 2007).

[3] These thresholds match those defined by Diabetes Canada (Punthakee et al., 2018). American Diabetes Association uses a threshold of 5.7-6.4% HbA_{1c} and 5.6-6.9 mmol/L FPG (Canivell & Gomis, 2014).

2.5 Patient Outcomes

In this thesis, three primary outcomes were examined: glycemic control, hospitalization, and mortality. Process of care was also examined as a secondary outcome. In this section of the literature review, each of these outcomes will be described, and the factors affecting these outcomes will be introduced and discussed. These factors will be situated within a conceptual framework. Complications are also discussed in this section. Complications are not an outcome of this thesis but are an important health outcome for patients with diabetes.

2.5.1 Glycemic Control

Glycemic control refers to the degree of hyperglycemia experienced by an individual. Hyperglycemia can be determined through blood glucose tests, such as fasting plasma glucose or HbA_{1c} testing. Plasma glucose testing determines the level of glucose in the bloodstream while HbA_{1c} testing measures the amount of glucose adhered to blood cells, providing a mean blood glucose level from the previous two to three months, although it is more representative of the previous 30 days (Berard et al., 2018).

For patients with T2DM, blood glucose levels are typically controlled through some combination of self-management (e.g., diet, physical activity), weight loss, and prescription (Diabetes Canada, 2018). For patients with T1DM, blood glucose levels are most often managed using insulin therapy, but physical activity and diet can also help regulate blood glucose levels (McGibbon et al., 2018). Metformin is usually the first choice of antihyperglycemic drug prescribed to patients with T2DM (Lipscombe et al., 2018). It is effective for lowering blood glucose levels, is safe, and appears on the list of essential medications from the World Health Organization (Lipscombe et al., 2018;

World Health Organization, 2017). For patients with T2DM who have high levels of hyperglycemia, insulin can be prescribed as a second-line antihyperglycemic agent. Insulin therapy is combined with other antihyperglycemic agents, such as metformin, and has been shown to effectively control glucose levels (Lipscombe et al., 2018). Other second-line medications for T2DM include DPP-4 inhibitors, GLP-1 receptor agonists, and insulin secretagogues such as meglitinides and sulfonylureas (Lipscombe et al., 2018).

Because glycemic control is an important indicator of diabetes management, many studies have examined the factors that are predictive of glycemic control. Several studies have found that, among individuals with diabetes, glycemic control improves with age (Al-Lawati et al., 2012; Benoit et al., 2005; Chiu & Wray, 2010; Martono et al., 2016). Conversely, most of these same studies have found that a longer duration of diabetes is associated with poorer glycemic control (Al-Lawati et al., 2012; Benoit et al., 2005; Chiu & Wray, 2010). From this research, it seems that being diagnosed with diabetes at a younger age may be associated with poor glycemic control across an individual's lifespan.

Other predictors of poor glycemic control include being uninsured, high cholesterol, and the use of pharmacological treatment (Al-Lawati et al., 2012; Benoit et al., 2005; Chiu & Wray, 2010; Martono et al., 2016). The relationship between pharmacological treatment and glycemic control may be explained by lifestyle. Chiu and colleagues (2010) found that 'good' lifestyle behaviours, such as vigorous activity and no substance use (drinking, smoking) were associated with a lower HbA_{1c} level, as compared to individuals with 'poor' lifestyle. Individuals who drink less and exercise more may be

able to manage their HbA_{1c} levels without medication, resulting in an apparent relationship between the use of pharmaceuticals and higher $HbA_{1c.}$

Although this study tested glycemic control as an outcome, it is also a significant predictor of complications and the other outcomes of this study: namely hospitalization and mortality. Patients with high blood glucose levels are at a greater risk of experiencing complications. Glycemic control targets developed by Diabetes Canada were designed to help patients reduce their risk of developing complications (Punthakee et al., 2018). Diabetes Canada provides clear recommendations through the publication of clinical practice guidelines; however, studies have shown that only around 50% of patients meet their targets for HbA_{1c} (Harris et al., 2005; Klomp et al., 2010; Leiter et al., 2013). HbA_{1c} has been shown to be a predictor of microvascular and macrovascular complications (Punthakee et al., 2018; Stratton et al., 2000). An observational study in the United Kingdom found that higher levels of HbA_{1c} were related to increased risk of stroke, amputation from peripheral vascular disease, and microvascular endpoints (retinopathy requiring photocoagulation, vitreous hemorrhage, and renal failure) (Stratton et al., 2000). These researchers also found that for every 1% decrease in HbA_{1c} levels, the risk of microvascular complications decreased by 37%, and the risk of any complication or death decreased by 21%. Finally, they did not find a threshold of hyperglycemia that resulted in complications or mortality, but blood glucose levels closer to normal were related to a lower risk of complications.

High blood glucose levels have been found to be related to an increased risk of hospitalization for patients with diabetes. Studies have explored the link between glycemic control and all-cause hospitalization (Al-Salameh et al., 2020; Bo et al., 2004;

Greisinger et al., 2004; Ho et al., 2006; Menzin et al., 2010; Moss et al., 1999; Tomlin et al., 2008; Wolters et al., 2017), as well as the link between glycemic control and hospitalization for specific diagnoses such as pneumonia (Kornum et al., 2008) and heart failure (Iribarren et al., 2001). These studies all found that, among patients with diabetes, the risk of hospitalization significantly increased for those with poor glycemic control. Poor glycemic control was also significantly related to an increased length of stay (Wilf-Miron et al., 2014). As previously mentioned, hyperglycemia is linked to micro and macrovascular complications, and, in addition, the authors of these studies suggest that poorly controlled diabetes makes patients more susceptible to infection than those with well-controlled diabetes (Kornum et al., 2008). Poorly controlled diabetes may be due to poor adherence to treatment (Ho et al., 2006; Iribarren et al., 2001), such as medication or lifestyle, or a lower quality of care (Dusheiko et al., 2011) which may lead to worsened outcomes and eventual hospitalization.

Poor glycemic control has been linked to higher mortality rates (Gerstein et al., 2008; E. S. Huang et al., 2011; Hunt et al., 2013; Riddle et al., 2010; Stratton et al., 2000; Wilf-Miron et al., 2014). While exploring the link between glycemic control and mortality among older patients with diabetes (>60 years old), some studies have found that there is a U- or J-shaped relationship between mortality rates and HbA_{1c} levels (Forbes et al., 2018; Gerstein et al., 2008; E. S. Huang et al., 2011). This finding indicates that, among older patients with diabetes, mortality rates are highest among individuals with above and below average HbA_{1c} levels. It may be that low HbA_{1c} levels may indicate the presence of other factors that can cause increased mortality rates, such as frailty or inadequate nutritional intake (E. S. Huang et al., 2011).

2.5.2 Complications of Diabetes

Although diabetes alone negatively affects one's health, those with the disease are at risk of various complications with a range of severity. Individuals with diabetes face an increased risk of cardiovascular disease (including heart attacks, stroke, heart failure), blindness, complications during pregnancy, poor oral health, and depression (Houlden, 2018; International Diabetes Federation, 2019). Those with diabetes are also at risk of nerve damage, most often in the lower limbs. Nerve damage can lead to injuries, infection, and amputation. Diabetes is the most common cause of non-traumatic lower-limb amputation in Canada (Public Health Agency of Canada., 2011). Diabetic retinopathy is the leading cause of blindness among Canadian adults. Diabetic retinopathy is a vascular disorder in which the permeability of blood vessels in the retina is increased (American Academy of Ophthalmology Retina/Vitreous Panel., 2016) leading to ischemia (lack of blood supply) within the retina due to bleeding, microaneurysms, and vascular abnormalities, which can lead to blindness. Finally, diabetes is also the leading cause of end-stage renal disease in high-income countries (Houlden, 2018; International Diabetes Federation, 2019). These various and often severe complications of diabetes are associated with early mortality among people with diabetes (Houlden, 2018; International Diabetes Federation, 2019).

2.5.3 Hospitalization

People with diabetes are hospitalized 2-3 times more often than people without diabetes (Donnan et al., 2000; Moss et al., 1999; Public Health Agency of Canada, 2011a). When comparing people with diabetes to people without diabetes, some conditions are more common causes of hospitalization among individuals with diabetes

than those without diabetes. These conditions include lower limb amputation (approximately 20 times the rate), end-stage renal disease (approximately 12 times the rate), chronic kidney disease (approximately six times the rate), and heart failure (approximately four times the rate) (Public Health Agency of Canada, 2011a). In the United States in 2004, the most prevalent conditions among patients with diabetes included chronic kidney disease (diagnosed in 27.8% of patients with diabetes), foot problems (foot/toe amputation, foot lesion, or numbness, 22.9%), eye damage (being told that diabetes had affected their eyes or had retinopathy, 18.9%), heart attack (9.8%), and coronary heart disease (9.1%) (Deshpande et al., 2008).

Treatment adherence has been found to be related to hospitalization. Studies have found that patients who are not adherent to their medication, such as oral hypoglycemic medications, are more likely to be hospitalized than those who adhere to their prescribed treatment (Ho et al., 2006; Lau & Nau, 2004). Among patients who are hospitalized, poor glycemic control can lead to worsened outcomes, such as increased rates of infection, complications, and mortality (Corsino et al., 2000).

2.5.4 Mortality

Mortality rates are higher among people with diabetes as compared to people without diabetes. The Public Health Agency of Canada estimates that one in every ten deaths in the country can be attributed to diabetes (Public Health Agency of Canada, 2011a). Additionally, adults with diabetes have a life expectancy of five to ten years shorter than adults without diabetes (Public Health Agency of Canada, 2011a). Canadian studies have shown mortality rates for patients with diabetes have been trending downward over time. In Ontario between 1995 and 2005, age-standardized mortality rates

significantly decreased (Lipscombe & Hux, 2007). In 1995, the age- and sex-adjusted mortality rate among people with diabetes was 17.6 deaths per 1000 people. In 2005, the rate was 13.3 deaths per 1000 people, representing about 25% fewer deaths among patients with diabetes in 2005 than in 1995. Lipscombe and Hux (2007) suggested that reduced mortality rates could be attributed to improved screening. This study was conducted in Ontario, and no new screening initiatives were initiated during the study period. Still, new screening guidelines were published during the study period, which may have increased public awareness of diabetes and a reduction of undiagnosed cases of diabetes.

The age-standardized mortality rate decreased for all Canadians between 2000 and 2015 (Public Health Agency of Canada, 2015a). For people without diabetes in Canada in the year 2000, there were 852 deaths per 100,000 people. This rate decreased to 613 deaths per 100,000 people by 2015. For people with diabetes in Canada, the age-standardized mortality rate decreased from 1,689 deaths per 100,000 people in the year 2000 to 1,119 deaths in 2015. The mortality rate among people with diabetes is almost twice the rate of mortality among people without diabetes. However, the difference in mortality rates between people with and without diabetes decreased between 2000 and 2015 (rate ratios of 1.98 in 2000 and 1.83 in 2015). The decrease in mortality rate indicates that people with diabetes in Canada were living longer in 2015 than in 2000. The patterns in mortality were similar in NL. In 2000, there were 1,899 deaths per 100,000 people with diabetes compared to 1,349 deaths among people without diabetes in NL. By 2015, death rates decreased for people with (1,461 deaths per 100,000 people) and without diabetes (739 deaths per 100,000 people). Although the mortality rate

decreased for both people with and without diabetes, the mortality rate ratio for people with diabetes increased from 1.41 in the year 2000 to 1.98 in 2015. This appears to be due to a substantial decrease in mortality among people without diabetes, from 1,349 to 739 deaths per 100,000 people, while the rate of mortality for people with diabetes did not see a similar decline (from 1,899 to 1,461 deaths per 100,000 people). Given the difference in mortality rates between people with diabetes in NL and Canada and people with and without diabetes in NL, these findings suggest that the health of people with diabetes in NL is worse than the national average, and there is a greater disparity in health between people with and without diabetes in NL.

Studies have explored whether increased screening for type 2 diabetes can reduce mortality, but the evidence is inconclusive. Statistical modelling of type 2 diabetes screening (Kahn et al., 2010; Waugh et al., 2007) suggests that increased screening could reduce cardiovascular complication rates, but these models do not translate into real-world success (Simmons et al., 2012). The Canadian Task Force on Preventive Health Care (Pottie et al., 2012) has determined that there is only weak, low-quality evidence supporting screening individuals at high or very high risk of T2DM and recommends that people with low to moderate risk of T2DM are not screened.

2.5.5 Process of Care

Process of care refers to the behaviours taken by care providers and the appropriateness of these processes for producing the desired outcome (Centers for Medicare & Medicaid Services, 2013). For patients with diabetes, the Diabetes Canada Clinical Practice Guidelines recommend multiple best practice processes for optimal diabetes management. For example, these guidelines suggest that patients with diabetes

receive a foot examination every year and eye examinations every 1-2 years, as well as annual cholesterol screening and kidney function tests (Altomare et al., 2018; Embil et al., 2018; Mancini et al., 2018; McFarlane et al., 2018). In addition, patients with diabetes should have their HbA_{1c} levels tested at least once every six months, but testing should be more frequent if they are not meeting their HbA_{1c} targets (Berard et al., 2013, 2018). Although there are many important components of diabetes care, the focus of this section will be laboratory testing, specifically glycated hemoglobin (HbA_{1c}), low-density lipoprotein cholesterol (LDL-C), and urine albumin-to-creatinine ratio (UACR). I have focused on laboratory tests because data for these tests are available for all patients in NL from a provincial database. Within this study, other important components of diabetes care, such as foot and eye care, and risk factors, such as blood pressure and lifestyle behaviours, cannot be examined because data are not available.

According to the CCHS, 83% of people with diabetes reported receiving one or more HbA_{1c} tests in the past year. Of the 83% who received testing, 40% reported having HbA_{1c} tested one to two times, and 60% reported three times or more (Canadian Diabetes Association, 2015). These rates are lower in NL, with only 75% of patients with diabetes receiving an HbA_{1c} test over 12 months in 2015 (Auditor General of Newfoundland and Labrador, 2016). The CCHS uses self-report data to ascertain the frequency of testing among Canadians with diabetes; however, testing frequency determined using secondary data sources occurs less frequently. Other Canadian studies have found that around 58-77% of patients with diabetes received an HbA_{1c} test in the previous year (Klomp et al., 2010; Lukewich et al., 2020; Woodward et al., 2006). The recent study from Lukewich and colleagues (2020) was conducted in NL using secondary data sources. This study

found that around 77% of people with diabetes in NL received at least one HbA_{1c} test in 2015, although only around half of those who received a test were meeting the recommended target (≤ 7.0%)

Two Canadian studies have found that younger, female, low-income individuals residing in rural regions are less likely to receive an HbA_{1c} test annually (Klomp et al., 2010; Woodward et al., 2006). Older individuals 50-70+ years of age are most likely to receive an HbA_{1c} test annually (Klomp et al., 2010; Woodward et al., 2006). Unsurprisingly, the frequency of HbA_{1c} testing has been shown to positively correlate with the number of physician visits (Woodward et al., 2006). Testing frequency also positively correlates with HbA_{1c} level; individuals with higher HbA_{1c} levels receive more frequent testing. This is congruent with the Diabetes Canada Clinical Practice Guidelines, which recommend that more frequent testing should occur if a patient is not meeting their target HbA_{1c} level. A meta-analysis was identified that explored the relationship between process of care and patient outcomes among patients with type 2 diabetes in the United States, which included glycemic control as measured by HbA_{1c} as an outcome (Egginton et al., 2012). This meta-analysis found that disease-management programs significantly reduced HbA_{1c} levels among patients with diabetes. Although promising, it is difficult to generalize from these results, given that the disease management programs included within this meta-analysis focused on several different care processes, including frequency of testing, dietary counselling, foot and eye examinations, and patient education.

There is less research on process of care outcomes related to LDL-C and UACR in comparison to HbA_{1c}. Research suggests that only approximately 50% of individuals with diabetes have received an LDL-C test in the previous year (Klomp et al., 2010). Similar to

HbA_{1c}, studies have found that individuals who are younger, female, of low income, and residing in rural regions are less likely to have received an LDL-C test in the previous year (Klomp et al., 2010). Among those who received an LDL-C test, only around 45% have been shown to meet target values (Klomp et al., 2010). A study conducted in Korea examined the relationship between adherence to clinical practice guidelines and several important outcomes for patients with diabetes. This study found that 84.9% of patients received an HbA_{1c} test in the previous year, but only 46.1% received an LDL-C test, and 33.5% received a UACR[4] test (Oh et al., 2011). This study also found that patients who did not receive an HbA_{1c} test were at higher risk of hospitalization and mortality. In addition, patients who did not receive an HbA_{1c} test were also less likely to have received a UACR test. Interestingly, patients who did receive a UACR test had a higher hospitalization rate than individuals who had not received a UACR test. Further research is needed to determine the relationship between testing frequency and outcomes such as hospitalization and mortality, particularly for underexplored testing, such as LDL-C and UACR.

Few studies have examined the relationship between processes of care, as determined by the frequency of laboratory testing and hospitalization or mortality. One Australian study examined the relationships between process of care variables and hospitalization (Comino, Islam, et al., 2015). This study found that increased physician

[4] A UACR test assesses the ratio of albumin to creatinine in the urine. Albumin is a protein that is typically filtered by the kidneys and high levels of albumin in the urine indicate decreased filtration by the kidneys. UACR is the "test of choice when screening for albuminuria" as it is easy to collect on a large scale and is not influenced by the volume of urine collected (McFarlane et al., 2018).

claims for HbA_{1c} and urinary micro-albumin were associated with a significant decrease in hospitalization. In contrast, physician claims for cholesterol testing were not significantly related to hospitalization. Interestingly, an increased number of overall FP claims was related to a significant increase in hospitalization. Other similar studies have found that poor adherence to practice guidelines is related to an increased number of hospitalizations (Huber et al., 2016; Oh et al., 2011).

One study, conducted in Italy, examined differences in mortality rates between patients with diabetes who were receiving guideline indicated care (i.e., two or more HbA_{1c} tests, and at least two of the following: eye examination, total serum cholesterol, and microalbuminuria) and those who were not receiving guideline indicated care (Giorda et al., 2012). All-cause mortality was lower among patients receiving guideline indicated care, regardless of whether they received care from only an FP or an FP and a specialist. Although there is limited research, evidence suggests that there is a relationship between poor process of care and mortality among patients with diabetes (Giorda et al., 2012; Oh et al., 2011).

2.6 Conceptual Framework

In 1973, Andersen and Newman developed a conceptual, behavioural framework for explaining and predicting health services use (Andersen & Newman, 2005). When the model was initially developed, the authors identified three main factors that determine one's use of health services; predisposing, enabling, and need (illness level). Figure 2.1 shows Andersen and Newman's framework for viewing health services utilization (2005), illustrating the relationship between social determinants, health services systems, and individual determinants. Societal determinants and health services system both act on

individual determinants, demonstrating how the external environment might determine an individual's ability to use health services.

This model has undergone multiple revisions since its initial development, and additional factors have been identified that may determine one's use of health services (Andersen, 1995). More recent updates of this model have highlighted the importance of the external environment (e.g., policy, physical environment), personal health practices, and organization of the health care system (e.g., health policy, resources, organization) (Andersen, 1995). Additionally, other researchers have explored integrating validated behavioural models into the Andersen and Newman model, such as the health beliefs model, to emphasize the relationship between health beliefs and health services use. Andersen (1995) identified several different outcomes the model could assess, including perceived or evaluated health status and satisfaction. Figures 2.1 and 2.2 show Andersen and Newman's framework for viewing health services utilization. For this thesis, secondary data will be used; therefore, some variables identified within the model (e.g., knowledge about disease, attitudes) will not appear in this literature review or subsequent analyses.

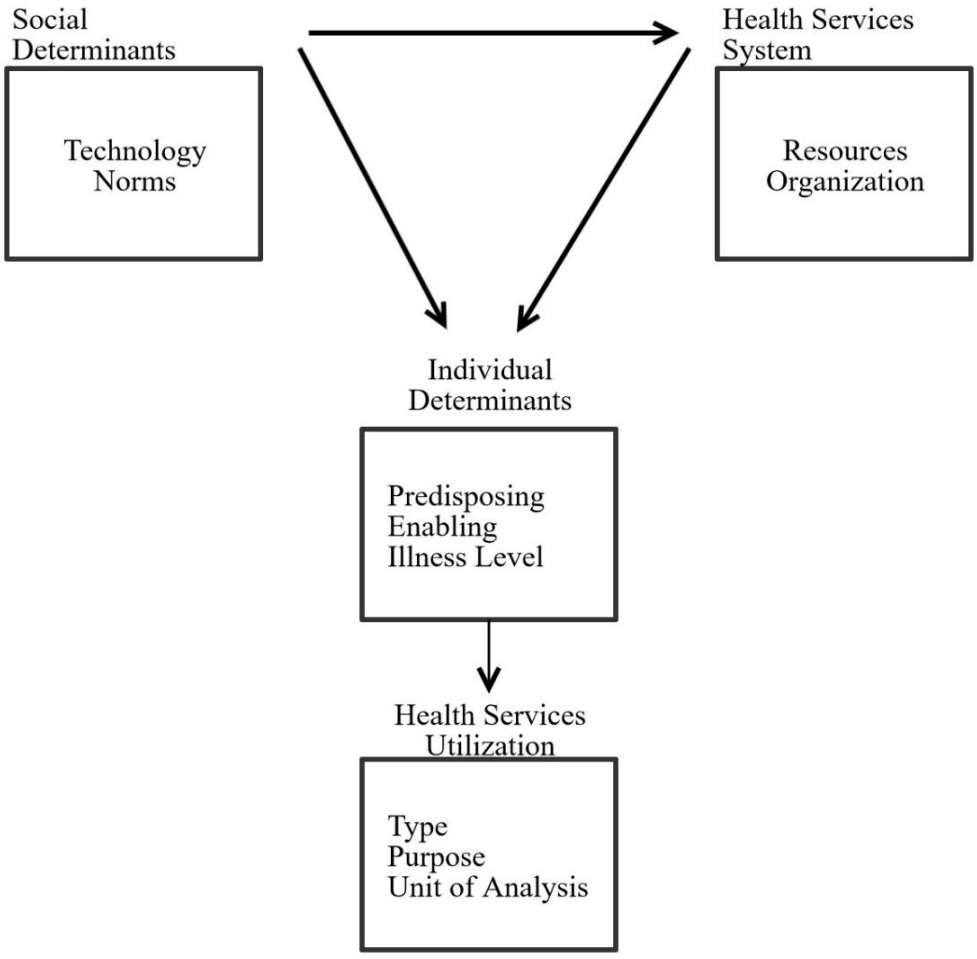

Figure 2.1

Andersen and Newman's Framework for Viewing Health Services Utilization

Reprinted from "Societal and Individual Determinants of Medical Care Utilization in the United States", by R. Andersen and J. F. Newman, 1973, The Milbank Memorial Fund Quarterly Health and Society, 51(1), pg. 98. Copyright 2019 John Wiley & Sons, Inc. Reprinted with permission.

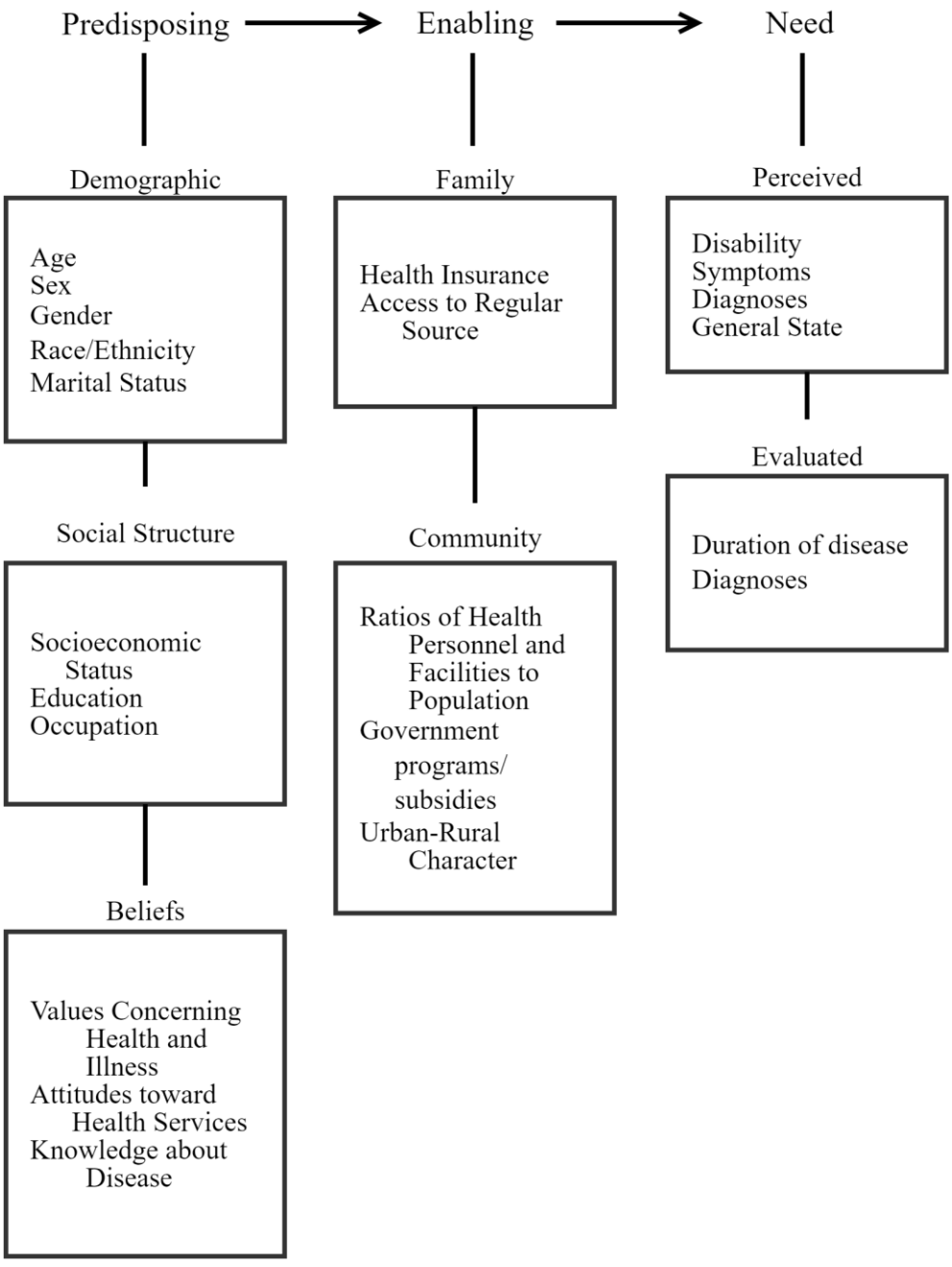

Figure 2.2

Individual Determinants of Health Service Utilization

Adapted from "Societal and Individual Determinants of Medical Care Utilization in the United States", by R. Andersen and J. F. Newman, 1973, *The Milbank Memorial Fund Quarterly Health and Society, 51*(1), pg. 108. Copyright 2019 John Wiley & Sons, Inc. Adapted with permission.

2.6.1 Predisposing Factors

Predisposing factors are individual characteristics, such as demographics, social structure, and beliefs, that play a role in an individual's health services utilization (Andersen & Newman, 2005). These factors are often difficult (e.g., attitudes, beliefs) or impossible (e.g., age, sex, past illness) to change. Other predisposing factors include social structure and health beliefs. Social structure is one's social standing within their community, often as a factor of occupation, ethnicity, and education. Finally, one's health beliefs will play a role in determining health service utilization. This section summarizes the evidence on predisposing factors and their relationship to health outcomes and risk factors for diabetes.

2.6.1.1 Sex. Sex plays a role in diabetes risk factors, treatment and complications. The Canadian Institutes of Health Research (CIHR) states that sex "refers to a set of biological attributes in humans and animals. It is primarily associated with physical and physiological features, including chromosomes, gene expression, hormone levels and function, and reproductive/sexual anatomy. Sex is usually categorized as female or male but there is variation in the biological attributes that comprise sex and how those attributes are expressed" (Canadian Institute for Health Information, 2014b, para. 2).

In Canada, the prevalence of diabetes is higher among males. In 2015-2016, the CCDSS estimated the age-standardized prevalence of diabetes as 7.1% among females and 8.8% among males (Public Health Agency of Canada, 2015a). Being male is considered to be a risk factor for developing type 2 diabetes (Kaczorowski et al., 2009), and studies have typically demonstrated that the incidence of diabetes is higher among males than females (Khan et al., 2011; Lipscombe & Hux, 2007); however, one study

found a significantly higher increase in prevalence among young females (20-49 years), as compared to young males, between 1995 to 2005 (Lipscombe & Hux, 2007).

The relationship between sex and glycemic control is undetermined. Some studies have found that females have poorer glycemic control than men (Wexler et al., 2005), while others have found no difference (Göbl et al., 2010). Wexler and colleagues (2005) found that females were less likely to meet the HbA_{1c} target of 7.0% and had higher cholesterol and blood pressure (Wexler et al., 2005), while Göbl (2010) did not find any sex-based differences in glycemic control among insulin-treated T2DM patients who were 60 years and older (Göbl et al., 2010). Sex differences in hospitalization rate may also depend on age. Moss et al. (1999) did not find significant sex-based differences among patients with diabetes, while a French study found that older females (aged 65 years and older) were less likely to be hospitalized than older males (Al-Salameh et al., 2020). Studies have found that mortality rates are higher among males with diabetes than females with diabetes (Al-Salameh et al., 2020; Hanefeld et al., 1996; Lipscombe et al., 2010; Lipscombe & Hux, 2007), although mortality rates due to cardiovascular causes are significantly higher among females (Hu, 2003; Kautzky-Willer et al., 2016; Roper et al., 2002).

2.6.1.2 Gender. CIHR defines gender as "…socially constructed roles, behaviours, expressions and identities of girls, women, boys, men, and gender diverse people. [Gender] influences how people perceive themselves and each other, how they act and interact, and the distribution of power and resources in society" (Canadian Institute for Health Information, 2014b, para. 3). Gender is often presented as a binary

(feminine/masculine) variable, but there is considerable variety in gender identities (e.g., non-binary, transgender).

Gender can refer to the role an individual plays within their society. In most families, women perform more unpaid housework such as cooking and caring for other members of the family (Y. Lee & Tang, 2015; Taillie, 2018). Patients with diabetes may require adjustments to their diet or care delivered by family members. Women often act as the predominant source of support for their male partners who have diabetes. Women can help their partners make lifestyle changes, particularly dietary changes (Mathew et al., 2012). In contrast, women with diabetes may not receive the same level of support from a partner who is a man. Instead, they receive support from a more extensive social network, such as friends, other family members, and support groups (Mathew et al., 2012; Wong et al., 2005).

When analyzing health data, CIHR recommends that results are presented stratified by sex or gender (Canadian Institutes of Health Research, 2016). Additionally, CIHR has suggested that researchers should perform additional analyses, examining the intersection of gender and other determinants of health. For example, some studies have found that women with diabetes experience a greater disadvantage due to poorer determinants of health as compared to men. Women of low socioeconomic status (SES) have a higher prevalence of diabetes than men of the same SES (K. Brown et al., 2015). Further, there is a greater difference in the prevalence of diabetes among women with the highest level of education compared to women with the lowest education (70%) than among men with the highest and lowest education (43%). These study results suggest that

social determinants of health have a greater impact on the health of women than men, and a sex- and gender-based analysis is required to quantify these differences.

The CCHS has found that the prevalence of T2DM is higher among men than women (Bird et al., 2015). Bird and colleagues (2015) examined the odds of developing T2DM by gender (men/women) and found that after controlling for age and overweight or obesity, men were 1.51 times more likely to develop T2DM than women. Although more men may have diabetes, glycemic control among women is worse due to the dual burden of caring for themselves and acting as the primary caregiver for their family (Siddiqui et al., 2013). As an example, women are more often responsible for grocery shopping and cooking for the household (Wong et al., 2005). Regardless, women with diabetes are less likely to report eating the same food as their family than men, suggesting that they modify the family's diet to care for their partner but are less likely to do so for themselves. Putting their families' needs ahead of their own may be one reason women have poorer glycemic control than men.

Rates of complications vary across gender. Men have higher rates of lower extremity amputation, but women have higher mortality rates related to lower extremity amputation (Kautzky-Willer et al., 2016; Peek, 2011). Similarly, more men undergo dialysis treatment, but women have higher mortality rates related to chronic dialysis treatment (Kautzky-Willer et al., 2016). Women have higher rates of cardiovascular complications, which have been suggested to result from increased psychosocial stress due to increased demands of diabetes that add to higher stress related to family responsibilities and discrimination (Kautzky-Willer et al., 2016). Although there can be differences in complication rates related to gender, it is unclear whether there are

differences in hospitalization (Comino, Harris, et al., 2015; Wolters et al., 2017) or mortality rates related to diabetes due to gender differences (Pan et al., 2017; Zghebi et al., 2017)

2.6.1.3 Race/Ethnicity. In Canada, the incidence and prevalence of diabetes can differ across ethnicities. Indigenous people in Canada have a much higher prevalence of diabetes than non-Indigenous people (Crowshoe et al., 2018; Shah et al., 2015). In 2011, a Canadian report found that the prevalence of diabetes was 17.2% among First Nations people living on-reserve, 10.0% among First Nations people living off-reserve, and 7.3% among Metis people compared to the prevalence of diabetes among non-Indigenous people in Canada, which was reported as 5.0% (Crowshoe et al., 2018). International studies have found that individuals of South Asian descent have a higher risk of developing T2DM while individuals of Chinese descent have a lower incidence (Khan et al., 2011).

Results of blood glucose testing vary across races. Studies have shown that HbA_{1c} levels among Black people are higher than that of White people who have the same blood glucose concentration, which suggests that HbA_{1c} over-predicts the blood glucose concentration of Black people (Bergenstal et al., 2017; Carson et al., 2016; Cavagnolli et al., 2017; Tsugawa et al., 2012; Ziemer et al., 2010). Participants of these studies were both individuals with diabetes and individuals without diabetes. The study from Carson and colleagues (2016) found that there were differences in HbA_{1c} levels only among those who had not been diagnosed with diabetes, suggesting that a higher HbA_{1c} threshold should be used to diagnose diabetes among Black people. To explore this, Tsugawa and colleagues (2012) examined rates of retinopathy among Black and White individuals.

This study showed that retinopathy was developing among Black people at *lower* HbA_{1c} levels than White people, arguing against a higher HbA_{1c} cut-off for Black people. More research is needed to determine the mechanism for this difference. Although the difference in HbA_{1c} testing between White and Black individuals has received a lot of attention, additional studies have identified differences across other ethnicities. Studies have also shown that Asian and Latino people have higher HbA_{1c} than White people with the same blood glucose concentration (Cavagnolli et al., 2017). Across all ethnicities, higher HbA_{1c} levels are associated with higher mortality rates (Hunt et al., 2013).

Racial differences have been found in complication rates. A study by Khan and colleagues (2011), conducted using data from Alberta and British Columbia, found that White patients had significantly higher rates of some cardiovascular complications and higher mortality rates than South Asian and Chinese patients. White patients also received a diagnosis of diabetes at an older age. Although the diagnosis did not occur until an older age, diabetes may have been present and untreated within the individual for longer, leading to a progression of the condition and a higher rate of cardiovascular complications and mortality. Racial differences can also contribute to the difference in risk of hospitalization. One **systematic** review from Wolters and colleagues (2017) found that African American people with diabetes are hospitalized more often than White Americans, and another study found that African Americans were nearly three times as likely to be hospitalized for diabetes than White Americans (D. L. Howard et al., 2007).

Given the differences in prevalence and hospitalization rates across different ethnicities due to diabetes, it is unsurprising that there are also differences in mortality rates across ethnicities. In Canada, mortality rates are significantly higher among

Indigenous and First Nations people. One study in Saskatchewan (Jiang et al., 2014) found that rates of end-stage renal disease were 2.4% among First Nations people with diabetes and 0.7% among non-First Nations people with diabetes. The diagnosis of type 2 diabetes at a younger age contributes to a higher risk of end-stage renal disease and higher mortality rates from diabetes (Dart et al., 2012; Dyck et al., 2014), although the incidence of end-stage renal disease is higher among First Nations people and is diagnosed at a younger age than among non-First Nations people (Dyck et al., 2010). A systematic review of studies primarily from the United States and the United Kingdom found that differences exist in mortality rates when comparing White people with diabetes to ethnic minorities with diabetes (Lanting et al., 2005). After controlling for confounding and other risk factors such as age, sex, socioeconomic factors, and health insurance, the differences were no longer significant, suggesting that differences in mortality rates across ethnicities may be due to confounding (e.g., socioeconomic status) or other risk factors and not ethnicity.

2.6.1.4 Socioeconomic Status. Socioeconomic status refers to an individual's position in society, often measured using a combination of education, income and occupation (American Psychological Association, 2017). SES can represent the social standing of an individual or group with an emphasis on the distribution of power based on status. SES has been consistently shown to impact the health of individuals. People of low SES may experience poorer health-related quality of life due to food insecurity, lower education, and receiving social assistance (Maddigan et al., 2006).

Incidence and prevalence of diabetes are higher among individuals with low SES (Dinca-Panaitescu et al., 2012; D. S. Lee et al., 2009; Lysy et al., 2013). Canadians in

low-income groups have a prevalence of diabetes three to five times that of individuals with high income (Dinca-Panaitescu et al., 2012; D. S. Lee et al., 2009). Higher rates of diabetes in lower-income groups have been suggested to result from poor health-related behaviours related to the incidence of diabetes (e.g., smoking, physical inactivity), but research does not always support this hypothesis (Dinca-Panaitescu et al., 2012). Health behaviours likely represent one contributing factor to the higher incidence and prevalence of diabetes among individuals with lower SES, but several other contributing factors complicate the relationship between SES and diabetes.

Income influences many areas of a person's life, such as their access to transportation, which may determine a person's ability to access health services or education which may affect a person's level of understanding regarding their disease and their ability to communicate with their health care provider (A. F. Brown et al., 2004; Conway et al., 2018). Research has found that neighbourhood SES is related to a greater risk of T2DM (Krishnan et al., 2010). Neighbourhood SES can be related to the opportunities individuals have for healthy food choices and physical activity facilities resulting in poorer diet, lower physical activity levels, and an ultimately higher risk of T2DM and poorer diabetes-related outcomes. As a result, low-income patients with diabetes have poorer outcomes than those with higher income on some measures (A. F. Brown et al., 2004; Conway et al., 2018; Maddigan et al., 2006).

Patients with low SES consistently have poorer glycemic control than patients of high SES (Houle et al., 2015; James et al., 2012; Jotkowitz et al., 2006). These findings are consistent across different countries, including Canada. The study from Houle and colleagues (2015) was conducted in Quebec and found that medication-taking predicted

HbA_{1c} levels only among people living in poverty and people with low education. It may be that people with low income may be underinsured and unable to afford necessary medications. They also may have competing demands that lead to lower adherence rates and poor self-management. One limitation of these studies is that SES is conceptualized as only income and education. A broader conceptualization, including food security, housing, and employment, might add some clarity to the complicated relationship between SES and diabetes outcomes.

In Canada, the publicly funded and administered health care system provides care for all medically necessary physician and hospital services. Although the disparity in health outcomes is less apparent than in the United States, individuals with low income in Canada have poorer health outcomes than individuals with higher income. Among Canadians with diabetes, having a low income is predictive of poorer health. Among patients with diabetes, individuals with lower income are significantly more likely to be hospitalized than individuals with higher income (Booth & Hux, 2003; Wolters et al., 2017). It is suggested that this difference in hospitalization rates may be due to differences in access to primary care services (Booth & Hux, 2003). Individuals with low income may not be able to navigate the health care system, or they may not have a car to travel to appointments or may not be able to keep appointments due to work or childcare (Booth & Hux, 2003). Additionally, diabetes supplies, such as testing strips for home blood glucose monitoring, are often not covered by insurance, which may contribute to the differences in hospitalizations across income levels (Booth & Hux, 2003).

Diabetes-related mortality rates have declined over the past 20-30 years. Still, the declines are significantly greater among high-income individuals than low-income

individuals (Lipscombe et al., 2010), resulting in high mortality rates among low-income patients with diabetes compared to patients with higher income (Pan et al., 2017). Lipscombe and colleagues (2010) suggested that the widening of the mortality gap between high- and low-income groups may be attributed to increased complexity and costs of diabetes care in Canada, resulting in higher medication costs, creating a cost barrier to those unable to afford these medications. In this study, the gap was lower among older individuals with universal drug coverage, offering support for this hypothesis.

2.6.1.5 Marital Status. Generally, married individuals are healthier and live longer than unmarried individuals (Kaplan & Kronick, 2006; Koball et al., 2010). There are several plausible reasons for this. Couples are more likely to have a higher shared income than single individuals, especially when compared to single women (Koball et al., 2010). Married people are more likely to have health insurance through their employer, and marriage offers strong social support that single people may not have (Koball et al., 2010). In the United States, married individuals are more likely to have better insurance through their partner for health care than single individuals (Kaplan & Kronick, 2006; Kim et al., 2006). One study conducted in the United States found that married individuals have better outcomes than unmarried individuals, such as increased screening rates for T2DM (Kim et al., 2006). Marriage may have a lesser impact in Canada and other countries with publicly funded health insurance, where all individuals have coverage for necessary health services.

Marriage can have a protective effect on diabetes risk and outcomes. Married women are less likely to develop T2DM than unmarried women (Schwandt et al., 2010).

There are a small number of studies that examined the effect of marital status on glycemic control. Two studies conducted in the United States did not find a significant relationship between marital status and glycemic control (Trief et al., 2017; Walker et al., 2014). One study, conducted in Saudi Arabia (Badedi et al., 2016), found that married individuals have better glycemic control than single or divorced individuals. Marriage has also been shown to reduce complications among individuals with diabetes, such as depression, mortality due to cardiovascular disease (Molloy et al., 2009; Simayi & Mohemaiti, 2019). Additionally, research has shown that unmarried men are more likely to die from diabetes than married men, but it is unclear what effect, if any, marriage has on the mortality rate of women (Schwandt et al., 2010). Although marriage can be protective for both men and women, often marriage offers a stronger protective factor for men than women, likely due to the traditional gender role that women play in the household (e.g., caregiving, cooking) (Molloy et al., 2009).

2.6.1.6 Weight/BMI. Body mass index (BMI) is the ratio of a person's weight in kilograms to their height squared (kg/m^2). Prevalence of diabetes increases with BMI (Bragg et al., 2018; Comino, Harris, et al., 2015; Field et al., 2001; D. S. Lee et al., 2009; O'Connor & Wellenius, 2012) and obesity has been found to be strongly related to the incidence of diabetes (Dinca-Panaitescu et al., 2012). Dinca-Panaitescu and colleagues (2012) found that Canadians who were obese were more than four times more likely to develop diabetes than people who were not obese. Additionally, data from the Nurses' Health Study found that those in the highest BMI category ($\geq 35.0 kg/m^2$) were 20 times more likely to develop diabetes than those with a BMI in the normal range (i.e., 18.5 kg/m^2–24.9 kg/m^2) (Field et al., 2001).

Although BMI is a risk factor for T2DM, the relationship between BMI and glycemic control among people with diabetes is less clear. Some studies have not found a significant relationship between BMI and glycemic control (Vázquez et al., 2014), while others have found a positive relationship between BMI and HbA_{1c} levels (Bae et al., 2016; Umeh, 2017). When examining the relationship between BMI and hospitalizations, studies have found conflicting evidence – both that there is no relationship between BMI and hospitalization (Moss et al., 1999) and that BMI significantly increases the risk of hospitalization for patients with diabetes (Bo et al., 2004). A study conducted in Taiwan (C. C. Lin et al., 2019) showed a non-linear relationship between BMI and hospitalization among a cohort of patients with type 2 diabetes. This study found that patients with a BMI of 23 – 27.5 kg/m^2 had a greater likelihood of all-cause hospitalization than individuals with higher ($\geq$ 27.5 kg/m^2) and lower BMI (18.5 - 23 kg/m^2 and < 18.5 kg/m^2). In fact, the study from C. C. Lin et al. (2019) found that, after controlling for age and gender, individuals with a BMI < 18.5 kg/m^2 had the greatest risk of hospitalization, as compared to individuals with higher BMIs. One study conducted in New Zealand (Tomlin et al., 2008) suggested that increased BMI may be associated with increased risk of hospitalization due to infection, but this study, as well as the study from C. C. Lin et al., did not find that BMI increased the risk of hospitalization due to other causes, such as hospitalization due to diabetes, renal-failure, or heart failure.

In the general population, there is a U-shaped relationship between mortality and BMI; the highest mortality rates occur among those with the highest and lowest BMIs (Menke et al., 2014). Among people with diabetes, some studies have found that the highest mortality rates among people with diabetes occur among those with low or

normal BMI, while other studies have not found significant differences in mortality rates associated with BMI (Carnethon et al., 2012; McEwen et al., 2012; Menke et al., 2014).

2.6.1.7 Adiposity. Although BMI is used as a measure of obesity, it does not directly measure body fat, nor does it capture the location or dispersion of body fat. The location and dispersion of body fat can be important for some chronic conditions, where abdominal body fat is a risk factor. Several studies have found that waist circumference, body fat percentage, or waist-to-hip ratio are better predictors of obesity-related T2DM than BMI (Gómez-Ambrosi et al., 2011; Neeland et al., 2012; Schulze et al., 2012), while some have found no difference in the predictive ability of waist circumference, body fat percentage, and BMI (Alvim et al., 2014; Bragg et al., 2018; Dervaux et al., 2008; MacKay et al., 2009). One study that examined body fat distribution found that liver and abdominal visceral fat were significant predictors of diabetes, but abdominal subcutaneous fat was not (Neeland et al., 2012).

Waist circumference is a strong predictor of insulin sensitivity. Individuals with a higher waist circumference have lower insulin sensitivity than those with smaller waist circumference (Wahrenberg et al., 2005; Wei et al., 2006). Further, body fat percentage is a stronger predictor of all-cause mortality and cardiovascular mortality than BMI (Gómez-Ambrosi et al., 2011). In terms of all-cause mortality rates among patients with diabetes, some studies have found that all indicators of adiposity (waist/hip ratio, waist circumference, waist/height ratio) are predictors of all-cause mortality among patients with diabetes (Sluik et al., 2011) while other studies did not find significant differences in mortality rates associated with adiposity (Menke et al., 2014).

2.6.2 Enabling Resources

Enabling resources are those that indicate the availability of health services to a person. Andersen and Newman's model identifies personal/family and community resources (Andersen & Newman, 2005). Personal resources are factors unique to an individual — income, health insurance coverage, having a regular source of care — that may act as facilitators or barriers to accessing health care services. Community resources refer to the state of health services within the community where one lives, including the ratio of service to the population and the cost of services. Services must be available to a person for them to make use of them. Patients with diabetes receive most of their care in a primary care setting; thus, it is essential that these patients have access to a regular source of primary care. Access to a regular source of care can be facilitated or hindered in different ways (e.g., availability and location of services; Penchansky & Thomas, 1981). Access to private insurance and other government-funded programs can also have an impact on patient outcomes.

2.6.2.1 Continuity of Care. Continuity of care is a principle of health care delivery, which may be conceptualized differently depending on the discipline. Although conceptualizations may differ, Reid, Haggerty and McKendry (2002) suggest that definitions of continuity of care need to contain two core elements; the individual experience of the care and care that occurs over time. Across disciplines, three types of continuity of care have been identified; relational, informational, and management continuity (Haggerty et al., 2003; Reid et al., 2002). Saultz (2003) also identified three types of continuity of care: informational and interpersonal continuity, which are analogous to Haggerty's informational and relational continuity, and longitudinal continuity. According to Saultz, longitudinal continuity means that individuals receive

care at the same place, where their medical information is housed, from the same team of providers (Saultz, 2003). Saultz places longitudinal continuity in a hierarchy between interpersonal and informational. Saultz identifies longitudinal continuity as a distinct type of continuity, while Haggerty suggests that a longitudinal relationship is necessary for continuity of care to exist. In Saultz's definitions, longitudinal continuity suggests that informational continuity is present over a series of visits to the same place but does not imply that an interpersonal relationship between patient and provider is formed.

2.6.2.1.1 Informational Continuity. Informational refers to data linking one provider to another or one health care event to another. It may refer to documented information (e.g., electronic medical records) but may also exist only in memory of the health care provider (Haggerty et al., 2003; Reid et al., 2002). This information may be disease-specific, but it can also include the patient's values, preferences, and context. Good informational continuity occurs when health care providers communicate with each other and with their patients (Haggerty et al., 2003; Reid et al., 2002). When health care providers communicate with the patient and share this information with other providers, it gives the patient a voice in their care (Haggerty et al., 2013).

2.6.2.1.2 Management Continuity. Management continuity refers to the continuity that occurs across different providers. Good management continuity occurs when services are delivered in a consistent, coherent, and timely manner (Haggerty et al., 2003). Management continuity is essential when patients have regular contact with a broad range of providers and may extend outside the health care system into social services (Reid et al., 2002). This type of care requires consistency over a long period and flexibility to meet the patient's changing needs. Management continuity is also an

important aspect of good primary health care (Burge et al., 2011). In this setting, care may be delivered by a team of health care providers, requiring coordination between team members. Within primary care, the primary care physician plays a central role in facilitating the transfer between other providers (Reid et al., 2002).

2.6.2.1.3 Longitudinal Continuity. Saultz's longitudinal continuity refers to "an ongoing pattern of health care interaction that occurs in the same place, with the same medical record, and with the same professionals, so that there is a growing knowledge of the patient by those providing the care" (Saultz, 2003, para. 8). This definition identifies the temporal aspect of continuity as a unique and important type of continuity that emphasizes the importance of continuity with a place of practice, as opposed to continuity with a single provider. Similarly, Starfield (1992) identified longitudinality as one of the four elements of primary care. In Starfield's definition, there is not a distinction between the longitudinal relationship between a patient and a physician, a team, or a place of care, but it is noted that the necessary aspect of longitudinal continuity is the personal relationship over time; patients should be able to identify their own personal source of care.

2.6.2.1.4 Relational Continuity. Relational continuity is the relationship between the patient and their clinicians. This continuity spans multiple episodes of care and links past and future care. This type of continuity is said to be most valued in a primary care setting (Haggerty et al., 2003). In this setting, relational continuity typically refers to the relationship between the patient and a single care provider (i.e., their FP). For good relational continuity in a primary care setting, the patient and their physician must have contact and communication over time. This sustained contact can result in the patient

having increased trust and loyalty to their physician and the physician feeling an increased sense of responsibility for their patient and their health (Haggerty et al., 2003). Research has supported this relationship, showing that sustained contact with a regular physician can result in increased trust and patient satisfaction (Mainous et al., 2001; Saultz & Albedaiwi, 2004)

2.6.2.1.5 Relational vs. Longitudinal Continuity. It is difficult to separate the concepts of relational and longitudinal continuity. Saultz's definition of longitudinal continuity suggests a sort of relationship would arise over a long period. Some studies have indicated that longitudinal continuity improves patient outcomes, but these studies have not sufficiently separated the concept of longitudinal from relational continuity (Hansen et al., 2013; Hoertel et al., 2014; Weiss & Blustein, 1996). It may be that longitudinal continuity acts as a proxy for relational continuity. One study from the United Kingdom compared patient outcomes between patients who had been registered with a practice for 50 or more years to patients who had been registered with the practice for 2-4 years (White et al., 2016). This study found that there were no significant differences between the different patient groups on the prevalence of most chronic diseases, medication use, or use of general practice or hospital services. This study had some limitations (low sample size, selection bias), but findings suggest that longitudinal continuity alone may not be enough to improve patient outcomes; it may, in fact, be the relationship that is developed that affects outcomes. Another study including both physician continuity and site continuity as predictors of complications and mortality among patients with T2DM found that site continuity was protective against some complications but was secondary to physician continuity (Liao et al., 2015).

2.6.2.1.6 Measures of Continuity of Care. Compared to the other types of continuity of care identified by Reid et al. (2002), researchers most often examine relational continuity (Van Walraven et al., 2010). Relational continuity has been operationalized based on the concentration and distribution of visits using physician billing data. Commonly used indices of continuity of care include the usual provider continuity (UPC) index (Breslau & Reeb, 1975; Reid et al., 2002), continuity of care (COC) Index (Bice & Boxerman, 1977; Reid et al., 2002), sequential continuity index (SECON) (Reid et al., 2002; Steinwachs, 1979), and modified modified continuity index (MMCI) (Magill & Senf, 1987; Reid et al., 2002).

The UPC index (Breslau & Reeb, 1975) is an indication of the concentration of visits to an individual's usual provider of care. It is a relatively simple calculation, using a ratio of the number of visits to one's usual provider to the total number of visits to any provider. The formula for calculating continuity of care using the UPC index is below (reproduced from Dreiher et al., 2012).

$$UPC\ index = \frac{n_i}{N}$$

where n_i is the number of visits to one's usual provider, and N is the total number of visits to all providers.

The COC index (Bice & Boxerman, 1977) is calculated using the sum of the number of visits to each provider divided by the total number of visits to all providers. When calculating this index, visits to referred providers may be attributed to the referring provider (Reid et al., 2002). The formula for calculating continuity of care using the COC index is below (reproduced from Dreiher et al., 2012).

$$COC\ index = \frac{\sum_{i=1}^{k} n_i^2 - N}{N(N-1)}$$

where n_i is the number of visits to an individual provider, k is the total number of providers seen, and N is the total number of visits to all providers.

It is scored on a 0-1 scale, where 1 indicates that all visits were to the same provider and 0 indicating all visits were to a different provider. The primary difference between the UPC and COC index is that UPC represents the concentration of visits to a *single* provider, while the COC Index creates a score based on the dispersion of visits across *any number* of providers.

SECON (Steinwachs, 1979) is used for measuring short-term continuity of care. It indicates whether sequential visits were to the same provider. Again, scored on a 0-1 scale, where 1 indicates all visits were made to the same provider and 0 indicates each visit was made to a different physician than was seen in the previous visit. The formula for calculating continuity of care using the SECON is below (reproduced from Dreiher et al., 2012).

$$SECON = \frac{\phi_i + \cdots + \phi_{N-1}}{N-1}$$

where ϕ_i indicates whether two sequential visits (value of 0 or 1) were to the same provider and N is the total number of visits to all providers.

The MMCI indicates the dispersion of visits across different providers. The calculation uses the total number of providers seen divided by the total number of visits resulting in a maximum score of 1. A score of 1 indicates all visits were to the same provider, while a lower score indicates multiple providers were seen over the total visits.

The formula for calculating continuity of care using the MMCI is below (reproduced from Dreiher et al., 2012).

$$MMCI = \frac{1 - \frac{k}{N + 0.1}}{1 - \frac{1}{N + 0.1}}$$

where *k* is the total number of providers seen, and *N* is the total number of visits to all providers.

These four measures have their own strengths and weakness, and the decision on which one to apply should depend on the research question. The UPC Index shows the concentration of visits to a single provider. This index is simple to calculate and widely used to indicate the strength of the longitudinal relationship between a patient and their usual provider (Reid et al., 2002). Given that it only captures the strength of the relationship between the patient and a single provider, it offers no indication about a patient's care coordination (i.e., number of providers seen, distribution of visits, or care delivered by a team). This measure is also affected by utilization rates; those with low utilization may have some of the highest scores (Reid et al., 2002). The COC Index can capture the strength of the relationship between the patient and a single provider as well as continuity of care across different providers. It incorporates the number of providers seen by a patient and the dispersion of visits across these providers. Regardless, the COC index is highly correlated with the UPC index and is more difficult to calculate, resulting in preference towards the UPC index (Reid et al., 2002). Additionally, the COC index does offer some indication of continuity of care between providers, but it does not indicate patterns or sequences of utilization. The score is difficult to interpret, except on

either end of the scale (0 or 1). Like the UPC index, it may also be high for low users and fall with increasing utilization (Reid et al., 2002).

Scores on the SECON show whether a patient has seen the same provider in sequence and assesses whether there was a need to share information between providers following a handoff (Dreiher et al., 2012). It is best used to calculate short-term continuity of care. SECON may be more difficult to calculate than COC and UPC, as it requires dates and provider details. SECON has been suggested to have lower correlations with COC and UPC (Pollack et al., 2016) and is not sensitive to changes in the total number of visits or providers seen or proportion of visits to the same provider (Reid et al., 2002; Steinwachs, 1979). Finally, MMCI is easy to use and only requires summaries of visits for an individual. The MMCI accounts for the number of providers seen over a number of visits but does not account for the sequencing of these visits (Reid et al., 2002). Compared to the three previous measures detailed, the MMCI is used less frequently and has not been well validated (Reid et al., 2002).

When comparing three indices of continuity of care (UPC, COC, SECON) among a sample of older adults with diabetes, Knight et al. (2009) found that scores on the COC index were lower than the other two measures. Because the COC index is calculated using the number of visits across all providers, this finding suggests that patients with diabetes have regular visits with multiple providers (Knight et al., 2009). Another study on the hospitalization rates of patients with diabetes compared four measures of continuity of care: UPC index, COC index, SECON, and integrated continuity of care index (Cho et al., 2015). This study found that all four measures had a negative relationship with hospitalizations, but the COC index had the most explanatory power,

although the difference was slight. As outlined previously, each measure of continuity of care captures a different aspect of continuity (e.g., the concentration of visits, distribution of visits across providers). Because there was only a slight difference between the various indices, Cho and colleagues (2015) suggest that the most critical factor when choosing an index is that the index of choice is suitable for answering your research question.

Patients with good continuity of care have been found to have better glycemic control than patients with poor continuity (Lustman et al., 2016). Differences in glycemic control between patients with good and poor continuity of care are likely attributed to patients with good continuity of care receiving care congruent with clinical practice guidelines (Lustman et al., 2016). Many studies have examined the effect of continuity of care on hospitalization rates among patients with diabetes. Studies have clearly shown that patients with diabetes who experience poor continuity of care are at an increased risk of hospitalization (Cho et al., 2015; Liao et al., 2015; W. Lin et al., 2009; Lustman et al., 2016; Weir et al., 2016; Wolters et al., 2017; Worrall & Knight, 2011). In addition, patients with diabetes who experience poor continuity of care are at an increased risk of death. A recent systematic review examined the relationship between continuity of care with a physician and mortality among patients with any condition (Gray et al., 2018). More than 80% of the 22 studies included in this review found that higher levels of continuity of care were related to lower mortality rates. Within this review, five studies focused solely on patients with diabetes, and all five of these found that poor continuity of care was significantly related to an increased risk of mortality (Liao et al., 2015; Lustman et al., 2016; Pan et al., 2017; Weir et al., 2016; Worrall & Knight, 2011).

2.6.2.1.7 Physician Turnover.

An alternative way of exploring continuity of care and availability of an FP is by examining the rate of turnover among physicians in a region. Turnover occurs when a physician leaves their position for any reason, including leaving to practice elsewhere, retirement, and death. The Canadian Institute for Health Information provides data on physician supply, distribution, and migration (Canadian Institute for Health Information, 2020b). Every year since 2001, NL has had a net loss of physicians to other Canadian jurisdictions, losing, with an average net loss of 29 physicians, with around 8 of those being family physicians (Canadian Institute for Health Information, 2020b). In 2019, 9.5% of family medicine physicians migrated from NL to another Canadian jurisdiction, twice the proportion of any other Canadian province. These statistics only capture the migration of physicians from one Canadian jurisdiction to another. They do not account for intraprovincial migration, nor do they account for retirements or death. The rate of physician turnover in NL is likely higher than these number suggest.

In 2006, the Institute of Clinical Evaluative Sciences introduced the concept of physician turnover as a measure of workforce stability representative of continuity of care, called "turnover index" (Tepper et al., 2006). Tepper and colleagues found that rural communities in Ontario experienced the highest levels of physician turnover. At the time this study was conducted (Tepper et al., 2006), there were more initiatives in place to recruit physicians to rural communities than there were initiatives to retain physicians within these communities.

The turnover index was calculated using the following equation:

$$\frac{|G + L| / 2}{N} * 100$$

where G = Number of new physicians gained by the community (i.e., were in practice in the year of interest but were not in practice in the preceding year).

L = Number of physicians lost by the community (i.e., were not in practice in the year of interest but were in practice in the preceding year).

N = Number of physicians in practice in the community in the year of interest (Tepper et al., 2006).

Scores on the turnover index can range from zero to 100, where a score of zero indicates that there were no physicians gained or lost in the region during the year of interest, while a score of 100 indicates that none of the physicians practicing in the year of interest are the same as those practicing in the community in the previous year. The importance of this measure is that it not only identifies changes in physician supply, but it also identifies whether the physicians practicing in a community in one year are the same as those who were there the previous year. By doing this, the turnover index provides an indication of whether patients in the community had access to the same physician year over year (e.g., maintained relational continuity).

Also in 2006, Alameddine and colleagues (2006) introduced measures of workforce stability. These measures are called “stickiness” and “inflow” and were developed to describe the attractiveness of workplaces for nurses in Ontario, although these measures can be applied to physicians as well.

Stickiness can be calculated using the following equation:

$$\text{Stickiness}_{t \text{ to } t+1} = \left[\left(N_{y,t\&t+1}/N_{y,t}\right)\right]*100$$

While inflow can be calculated using this equation:

$$Inflow_t = \left[\left(N_{y,t} - N_{y,t\&t-1}/N_{y,t}\right)\right] * 100$$

For both equations:

Ny,t = the number of physicians working in a region at time t

Ny, t&t+t = the number of physicians working in a region at both time t and time t +1

Stickiness is the number of physicians working in a region in the year of interest who are the same as those who were working in a region in the previous year, divided by the number of physicians working in the region during the last year. Stickiness is a score between zero and 100 where zero indicates that all physicians working in the region in the year of interest are different from those working in the region in the previous year, while 100 indicates that all the physicians working in a region in the year of interest are the same as those who were working in the region in the previous year. This measure is similar to the turnover index developed by Tepper et al. (2006).

Inflow is the ratio of the number of new physicians working in a region in the year of interest to the total number of physicians working in a region in the previous year. This score ranges from zero to 100, where zero indicates that there are no new physicians working in a region, while 100 means that all the physicians working in a region in the year of interest are new to the region. Both measures provide an indication of the attractiveness of a workplace. Inflow offers an indication of recruitment, while stickiness offers an indication of retention. Alameddine et al. (2006) showed that there was an inverse relationship between inflow and stickiness, as sectors that could retain health care providers (i.e., had high stickiness) had less need for recruitment (i.e., lower inflow).

The relationship between FP turnover and health outcomes for patients with diabetes has not been well explored. Knight et al. (2017) were the first to examine the relationship between retention and avoidable hospital admissions in NL. They found that poor retention was associated with an increase in avoidable hospitalization. Findings from the study by Knight and colleagues suggest that poor retention (or high turnover) may disrupt continuity of care, leading to a higher risk of hospitalization. Turnover provides a potentially valuable measure that can be used as a proxy for continuity of care when continuity of care cannot be measured using commonly used indices.

2.6.2.2 Urban/Rural Residence. In 2016, approximately 18.7% of Canadians resided in a rural region (Statistics Canada, 2019). This number is substantially higher in NL, where Statistics Canada estimates that 41.9% of residents live in a rural area (Statistics Canada, 2007). Among developing countries, urbanization is said to lead to more cases of diabetes (Dagenais et al., 2016). In high-income countries, such as Canada and the United States, the prevalence of diabetes is higher in rural regions (O'Connor & Wellenius, 2012). This higher prevalence may be due to the fact that individuals living in rural regions may experience poorer access to health services and health care providers, may have poorer education, have lower income, are older, are more likely to smoke, have heavy alcohol consumption, and are obese (G. Howard et al., 2017; Kapral et al., 2019; O'Connor & Wellenius, 2012). Some studies have shown that patients with diabetes living in rural areas may not be receiving recommended care in areas such as hypertension and diabetes management, diabetes screening, hyperglycemia, and dyslipidemia (Kapral et al., 2019; Supina et al., 2004; Toth et al., 2003). A study from the United States (O'Connor & Wellenius, 2012) found that the overall prevalence of

diabetes was significantly higher in rural regions, but, after controlling for risk factors (e.g., age, BMI, income, education), the prevalence was found to be higher in urban regions. In Canada, the highest prevalence of diabetes is found in the Atlantic provinces (Public Health Agency of Canada, 2011b), which may be attributed to the fact that people in Atlantic Canada experience poorer determinants of health, as compared to the rest of the country. Additionally, more individuals in Atlantic Canada reside in rural regions, which may contribute to individuals having poorer determinants of health (K. Brown et al., 2015; Statistics Canada, 2007).

A recent study in Ontario examined urban and rural differences in stroke risk (Kapral et al., 2019). This study found that patients living in rural regions had fewer visits to FPs and specialists and more visits to the emergency department. Rural residents also had an increased risk of stroke and all-cause mortality, suggesting that access to health services may be associated with an increase in all-cause mortality. Other similar studies have found that the risk of mortality is higher among individuals living in areas with less urbanization (Pan et al., 2017).

2.6.2.3 Insurance, Public and Private. The health systems of Canadian provinces publicly insure medically necessary physician and hospital services, but prescription drugs and health supplies are not insured under this program. Blood glucose self-monitoring supplies, such as test strips, may not be covered by the province's public insurance. Some people may receive private insurance through their employer or pay out-of-pocket for additional coverage. Those without private insurance would have to pay out-of-pocket for these health care products, limiting the accessibility of these products

for low-income patients and resulting in health disparities between individuals with and without private insurance.

Each province has supportive programs for people with high drug costs, older adults, and those with low income. In NL, the program is called the Newfoundland and Labrador Prescription Drug Program (Government of Newfoundland and Labrador, 2019). Individuals eligible for these programs may be responsible for copayments but would otherwise have the costs of their prescription medications paid for by the provincial government. Although these programs exist, there are people with low income who are without drug coverage. Families with income over $42,870 whose drug costs are not more than 5% of their net income (if their net income is $40,000 or less) would not be eligible for coverage from the NL government (Government of Newfoundland and Labrador, 2019). As a result, people who are above this threshold, most often those who are considered underemployed and underinsured, lack drug coverage.

This lack of insurance has an impact on adherence to treatment. Two Canadian studies examined the relationship between prescription drug use and insurance coverage among patients with diabetes (Kratzer et al., 2015; Shah et al., 2014). Among people under the age of 65, those with private insurance were more likely to use prescription drugs. At the same time, there were no differences among people over the age of 65, suggesting that the availability of public insurance of prescription drugs to older Canadians influences the use of prescription medications.

For patients with diabetes, test strips are needed to perform at-home blood glucose monitoring. The provinces and territories insure these strips, but the quantity of strips insured varies by jurisdiction, whether the patient is an insulin user, and whether they are

prescribed any medications. NL limits patients to 700 strips per year for those using long-acting insulin (Ontario Drug Policy Research Network, 2017). For those who are not using insulin but using other medications, the limit is 100 strips, and for those not using insulin or medications, the limit is 50 strips. Patients using short-acting insulin are limited to 2,500 test strips per year. For patients with T1DM treated with insulin, self-monitoring is related to lower HbA_{1c} (Berard et al., 2018). For T2DM, the benefits of self-monitoring are limited (Berard et al., 2018; Cordts, 2012).

The effect of private insurance on patients with diabetes has not been well explored in Canada. One study found that lack of insurance for diabetes testing supplies was related to poorer glycemic control among patients with T2DM (Bowker et al., 2004). This study also found that people without insurance were less likely to have a high school education and less likely to earn ≥ $40,000. Another study found that people with diabetes who were socially disadvantaged were at higher risk of stroke, non-fatal acute myocardial infarction, and death, as compared to more advantaged people (Booth et al., 2012). The relationship between social disadvantage and complications and mortality was more pronounced among individuals who were under the age of 65 years, which was suggested to be related to drug insurance (Booth et al., 2012). It is likely that the relationship between insurance and SES is intersectional; those with low SES have poorer health than those with high SES, but those with no drug coverage have poorer health among those with low SES.

2.6.3 Need

Need factors refer to a person's perceived or evaluated need for health service use. Perceived need refers to an individual's view on their own personal health and functional

state and includes beliefs about the level of illness or worries about their health. If a person believes they are sick enough to warrant care, they will likely seek care (Andersen, 1995). The second factor is evaluated need which is the level of illness as assessed by a medical professional. This evaluation determines the type and amount of care a person receives (Andersen, 1995).

2.6.3.1 Duration of Diabetes. The length of time a person has diabetes may affect their health. Multiple studies have shown that the duration of diabetes is related to poorer glycemic control (Benoit et al., 2005; E. S. Huang et al., 2011; Khattab et al., 2010; Nichols et al., 2013). It has been suggested that this relationship is due to progressive failure of the insulin-secreting cells in the pancreas. As a result, response to treatments is lessened, and glycemic control worsens (Khattab et al., 2010). Although a longer duration of disease is related to worse glycemic control, studies have found that younger age is also related to worse glycemic control (Badedi et al., 2016; Crowley et al., 2014; Rothenbacher et al., 2003). This finding may suggest that younger patients are facing additional barriers to glycemic control. One study found that duration of diabetes predicted complication and mortality rates independent of age (E. S. Huang et al., 2014), while other studies suggest that the relationship between duration of diabetes and hospitalizations and mortality may be attributed to glycemic control as opposed to duration of diabetes (Nichols et al., 2013).

2.6.3.2 Co-/Multimorbidity. Diabetes is associated with several other chronic, comorbid conditions. Within the literature, comorbidities are defined in temporal relation to an index condition (Valderas et al., 2009). Conditions that are comorbid with diabetes may come before or after a diabetes diagnosis. For example, diabetes and depression are

common comorbid conditions, but the temporal sequence of these conditions is not the same for every patient. Regardless of the temporal relationship, many patients with diabetes have multimorbidity, which is the presence of two or more chronic conditions (Valderas et al., 2009). Multimorbidity increases the complexity of disease management for patients with chronic conditions. Although clinical practice guidelines may discuss the management of multiple conditions, these guidelines are typically organized around one condition. Diabetes Canada include chapters on diabetes and mental health and treatment of diabetes in people with heart failure, but these chapters focus on the management of diabetes in the context of a comorbid condition, as opposed to focusing on the management of both conditions within a single patient (Connelly et al., 2018; Robinson et al., 2018). In 2011/12, the prevalence of multimorbidity (having 2+ chronic conditions) in Canada was 26.5% (Feely et al., 2017). The prevalence of multimorbidity among people in NL is one of the highest among Canadian provinces and territories. In 2011/12, 28.1% of people in NL had two or more chronic conditions, and 10.2% had three or more chronic conditions (Feely et al., 2017). Using data from the 2011/12 CCHS, Roberts and colleagues (2015) found that the prevalence of multimorbidity among Canadians aged 20 years and older was higher among women, older people (65+ years), those with low income or education, those self-identifying as Aboriginal, and those born in Canada (i.e., lower prevalence among immigrants). This study from Roberts et al. (2015) also found that diabetes and arthritis was the third most common disease dyad, affecting 35.2% of people with two or more chronic conditions and arthritis, diabetes, and heart disease was the second most common disease triad, affecting 15.1% of people with three or more chronic conditions. Some of the most common conditions among patients with diabetes

include arthritis, mental disorders (mood disorders such as depression or anxiety), asthma, and heart disease (Roberts et al., 2015).

A recent Canadian study showed that as age and the number of chronic conditions increased, so did the average number of visits to a family doctor (Griffith et al., 2019). Additionally, patients with multimorbidity have an increased likelihood of hospitalization compared to individuals with a single chronic condition, and the likelihood of hospitalization increases with the number of chronic conditions (Gruneir, Bronskill, et al., 2016). Gruneir and colleagues (2016) examined the association between multimorbidity and hospitalization while controlling for demographics and continuity of care. Continuity of care modified the odds of hospitalization, as patients with poor continuity of care had a greater likelihood of being hospitalized as compared to individuals with good continuity of care.

2.7 Conclusion

In summary, diabetes is a prevalent chronic condition affecting a higher proportion of people on average in NL as compared to the country as a whole. Although diabetes can be managed, if poorly controlled, diabetes can lead to hospitalization and mortality. In Canada, patients with diabetes rely on a primary care provider to help manage their condition. Regular appointments with a provider are recommended, but factors such as family physician turnover may influence a patient's ability to access primary care services. Andersen and Newman's Behavioural Model of Health Services Utilization can be applied to identify factors that are associated with health outcomes for patients with diabetes. This model identifies three groups of factors; predisposing, enabling, and need; and variables from each of these categories will be used in the

analyses to determine how these factors are related to glycemic control, hospitalization, and mortality. Previous research has established that continuity of care is an important predictor of health outcomes for patients with diabetes. Unfortunately, commonly used measures of continuity of care cannot be calculated for patients with diabetes in NL. Thus, this study uses FP turnover as a proxy measure of continuity of care, examining how the turnover of FPs in NL is affecting patients with diabetes in NL.

Chapter 3: Methods

3.1 Overview

This study used secondary data to carry out a cross-sectional analysis to identify factors related to glycemic control, hospitalization, and mortality among people with diabetes in Newfoundland and Labrador (NL). Data from the Chronic Disease Registry (formerly the Provincial Diabetes Database), MEDITECH, Provincial Discharge Abstract Database (PDAD), and the Physician and Medical Practice Database were used in these analyses. This study employed multivariate logistic regression analyses to examine the relationship between family physician (FP) turnover and glycemic control, hospitalization, and mortality among patients with diabetes in NL. FP turnover was the primary predictor of interest and covariates were tested within the regression models to identify factors that are predictive of the outcomes of interest.

3.2 Data Sources

Patient data from the Chronic Disease Registry, the MEDITECH database, and the PDAD were requested from the Newfoundland and Labrador Centre for Health Information (NLCHI). Physician data were extracted from the Physician and Medical Practice Database. For all datasets, data from the fiscal years of 2011/12 to 2015/16 were used (April 1st, 2011 to March 31st, 2016). Appendix A identifies and describes all requested variables.

3.2.1 Chronic Disease Registry

The Chronic Disease Registry is a longitudinal database maintained by NLCHI (Newfoundland and Labrador Centre for Health Information, 2018a). This database was established in 2017 and includes seven chronic diseases: diabetes, asthma, chronic

obstructive pulmonary disease, heart failure, hypertension, ischemic heart disease, and stroke. The Chronic Disease Registry uses validated disease case definitions to identify individuals within the population who have a disease of interest. For this study, only data for patients with diabetes were requested and used.

The Chronic Disease Registry uses two case definitions to identify cases of diabetes. The first definition is that of the Canadian Chronic Disease Surveillance System (CCDSS), which classifies an individual as having diabetes if they have ≥ 1 hospitalization(s) or ≥ 2 physician visits with a diabetes diagnosis code within a two-year period (Public Health Agency of Canada, 2015a). This definition has been validated in Ontario and has 86% sensitivity, 97% specificity, and 80% positive predictive value (Hux et al., 2002). To the best of my knowledge, this case definition has not been validated in NL. The second case definition uses laboratory data to identify cases of diabetes within the population. An individual is classified as having diabetes if they have any of the two following test results in a two-year period: fasting plasma glucose test result of ≥ 7 mmol/L; HbA_{1c} test results of ≥ 6.5%; two-hour plasma glucose in a 75g oral glucose tolerance test result of ≥ 11.1 mmol/L; or random plasma glucose test result of ≥ 11.1 mmol/L. This definition is the same as the diagnostic criteria set by Diabetes Canada (Goldenberg & Punthakee, 2013; Punthakee et al., 2018) and individuals with blood glucose levels above these thresholds are at risk of developing microvascular complications. The Chronic Disease Registry excludes individuals who have gestational diabetes. Once individuals are identified as having diabetes, their data within the Registry (e.g., age, place of residence) are updated annually until they move out of the province or die. For this study, the sample was identified from the Chronic Disease Registry. The

Registry provided relevant demographic data for the population used in this study (e.g., age, sex, place of residence) and information about their disease (e.g., case source).

3.2.2 Provincial Discharge Abstract Database

The PDAD was implemented in 2014/15 to replace the Clinical Database Management System (Newfoundland and Labrador Centre for Health Information, 2017). Health care facilities in the province that provide surgical day care, acute care, or other forms of long-term or chronic care[5] in acute and surgical day care facilities in the province submit data to the PDAD. This database contains details of all hospitalizations and surgical daycare cases in the province, including the facility where the episode took place and details of the patient and the care episode.

For this study, I examined hospitalization data for 2011/12 to 2015/16 from the PDAD for patients with diabetes, including hospital admission and discharge dates, most responsible diagnosis, and type of care episode (e.g., acute, surgical day care, chronic care). Only hospital admissions were included within these data (e.g., overnight stay). For this study, only episodes of acute care hospitalizations were used as an outcome.

3.2.3 MEDITECH data

Each of the hospitals and medical laboratories within NL's four Regional Health Authorities submits data to a centralized MEDITECH database. MEDITECH data include laboratory data, diagnostic imaging reports, emergency room triage data, and encounter notes (Newfoundland and Labrador Centre for Health Information, 2018b).

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[5] The custodian of the PDAD recommends that caution is exercised when using chronic or long-term care data, as chronic care data are not reported by all facilities every year (Newfoundland and Labrador Centre for Health Information, 2017)

For this study, relevant laboratory testing data from MEDITECH were used. The three tests of interest were glycated hemoglobin (HbA_{1c}), low-density lipoprotein cholesterol (LDL-C), and urine albumin-to-creatinine ratio (UACR). For all patients with diabetes in NL, laboratory data corresponding to these three tests were used in this study, including the date and value of each HbA_{1c}, LDL-C, and UACR test performed during 2011/12 to 2015/16. LDL-C and UACR test values were used as covariates in this study. HbA_{1c} test results were examined both as a covariate and an outcome, representing glycemic control.

3.2.4 Physician and Medical Practice Database

The Physician and Medical Practice Database is a longitudinal dataset containing information on all physicians in NL. Dr. Maria Mathews, currently at the Centre for Studies in Family Medicine at the Schulich School of Medicine and Dentistry, Western University, is the creator and custodian of this database. This database was developed by linking data from the College of Physicians and Surgeons of Newfoundland and Labrador, the provincial Medical Care Plan (MCP), the Canadian Institute for Health Information's National Physician Database, and Scott's Medical Database. The Physician and Medical Practice Database was funded by the Canada Foundation for Innovation and the Newfoundland and Labrador Industrial Research and Innovation Fund. This database includes physician demographic data such as gender, the medical school they graduated from, year of graduation, and specialty certifications. The database also contains details on the physician's practice, such as the current and former addresses of practice and the start and end dates of their employment at each practice.

For this study, each physician's current and former addresses of practice, start and end dates of employment for each practice, and specialty certifications were used to calculate FP turnover for each economic zone. Additionally, the database was used to determine the number of physicians per 1,000 people within each economic zone.

3.2.5 Linkage of Datasets

The datasets used in this study were linked using patient or geographic identifiers. The Chronic Disease Registry, MEDITECH, and PDAD provide a unique identification code for each patient. This code is created by NLCHI and is deterministic based on the patient's MCP number. This patient identification code was used to link the three datasets (i.e., Chronic Disease Registry, MEDITECH, PDAD). FP turnover and the number of FPs per 1,000 people were calculated at the level of the economic zone. The Physician and Medical Practice Database were linked to the patient-level data using economic zone.

The geographic level of economic zone was used in this study because it represents a region with a shared labour market where people commute to work and where communities share public services and have a high level of interaction (Rural-Urban Interaction NL, 2010). Because of this high level of interaction, it is posited that economic zones represent accessibility of physician care, as people are likely to travel within that zone to access their FP. There are 20 economic zones in NL, representing relatively large geographic areas. A map of economic zones in NL is provided in Appendix D If analyzed at a smaller level of geography, some regions would have very few or even no FPs. For regions with few FPs, the turnover of a single physician would result in a substantial change in physician turnover score; therefore, a larger geographic area of economic zone was an appropriate level of geography for the analyses.

The Chronic Disease Registry provides patients' census subdivision of residence. Census subdivisions were rolled up into economic zones to link with the Physician and Medical Practice Database. The NL Statistics Agency provided the necessary data to roll up census subdivisions to economic zones (H. Ryan, personal communication, October 19, 2019). These data indicated which economic zones contained which census subdivision, which allowed us to deterministically link census subdivision and economic zone. There were 372 census subdivisions in NL in 2016 (Statistics Canada, 2018). Seven census subdivisions (1.89%) are split across economic zone boundaries. The total population of these split census subdivisions is 5,070 people (approx. 0.98% of the population of NL) (H. Ryan, personal communication, October 18, 2019). To address this split, all individuals within the split census subdivision were assigned to the economic zone that contained the greatest proportion of the population of the split census subdivision.

3.3 Population

This study includes all people in NL with type 1 and type 2 diabetes from 2011/12 to 2015/16.

3.3.1 Inclusion

For this study, only patients with prevalent cases of diabetes at the end of the 2010/11 fiscal year were included. They must not have moved economic zones or into or out of the province between 2011/12 and 2015/16.

3.3.2 Exclusion

The Chronic Disease Registry excludes all cases of gestational diabetes. During data cleaning, individuals missing age or sex were excluded because a review of the

literature has established that these variables can significantly impact outcomes for patients with diabetes. Those missing place of residence were excluded because, without this variable, data from the Physician and Medical Practice Database could not be linked with these individuals; therefore, they could not be assigned a turnover score.

Patients were excluded if they moved during the study period as they may have experienced disruptions in continuity of care that could not be attributed to physician turnover. NLCHI updates patient demographic data annually. Individuals who moved to a different economic zone within the province or a different province were removed from all analyses. Individuals who had a change in their economic zone between 2011/12 and 2015/16 were identified as having moved within the province and were excluded from all analyses. Individuals who changed census subdivision but remained within the economic zone were retained. Economic zones represent areas of the province with a shared economy, where residents travel within to work and access services; therefore, it is plausible that a patient would retain the same FP if they moved communities but remained within the economic zone. The Chronic Disease Registry is updated annually, and individuals are not included in the updated data if they have moved out of the province. Individuals with missing years of data without a year of death were assumed to have moved out of the province and were excluded from the analyses.

Individuals identified as having diabetes by the CCDSS case definition alone were excluded from the analysis to avoid potential bias. Because hospitalization was an outcome of interest, using hospitalization as an outcome and a selection criterion may have biased this outcome. Further, because the CCDSS case definition only identifies those with hospitalization or physician billing data, this case definition would

underrepresent individuals whose FP did not submit billing data. Because many non-fee-for-service physicians work in rural regions, and individuals residing in rural areas of the province are older, individuals identified by the CCDSS case definition alone were excluded. Sensitivity analyses are presented in Appendix F to determine whether the exclusion of these individuals may have affected the results of the study. The number of individuals excluded is outlined in Chapter 4 and appears in Figure 4.1 (flow chart of inclusion and exclusion criteria).

3.4 Variables

Covariates were identified through a review of the literature. From the variables that were identified in the literature review, those that are available within existing databases (e.g., Chronic Disease Registry, Physician and Medical Practice Database) were included in the analyses. These variables are grouped into predisposing, enabling, and need according to Andersen and Newman's Behavioural Model of Health Services Utilization. Process of care variables (i.e., testing frequency) were also included within supplementary analyses. Table 3.1 describes the outcome and predictor variables, organized according to the Andersen and Newman framework

Table 3.1

Outcome and Predictor Variables, Organized According to the Andersen and Newman Framework

Predisposing variables	Enabling variables	Need variables	Process of care variables	Outcomes
Sex (Individual)	Rural resident (Individual)	LDL-C (Individual)	Frequency of HbA_{1c} tests match guidelines (Individual)	[Glycemic control] (Individual)
Age (Individual)	Number of FPs per 1,000 population (Economic zone)	UACR (Individual)	Frequency of LDL-C tests match guidelines (Individual)	Hospitalization (Individual)
	Physician turnover (Economic zone)	[Glycemic control] (Individual)	Frequency of UACR tests match guidelines (Individual)	Mortality (Individual)
	Number of acute care beds per 1,000 population (Economic zone)			

FP – family physician; LDL-C - low-density lipoprotein cholesterol; UACR - urine albumin-to-creatinine ratio; HbA_{1c} – glycated hemoglobin

[ ] are used to indicate that the variable appears twice in this table and was used as a covariate and as an outcome

( ) are used to indicate whether the variables were calculated at the individual level or at the geographic level of economic zone

3.4.1 Predisposing Variables

3.4.1.1 Sex. Sex appears in the Chronic Disease Registry as the sex that patients listed on their MCP record. Female was coded as 0, and male was coded as 1. Sex was tested as a covariate in all analyses.

3.4.1.2 Age. NLCHI provided age within the dataset as the patient's age in years at the end of a given fiscal year (i.e., March 31st). Age was derived by NLCHI using the patient's MCP record. The age of the patient at the end of the 2015 fiscal year was used as a covariate in this thesis. The interval age variable was recategorized into ordinal age

groups, applying the same groups as CCDSS (Public Health Infobase, 2020). CCDSS uses six age groups that represent life course age groups (0-19, 20-34, 35-49, 50-64, 65-79, 80+). Individuals who were younger than 20 at the end of the 2011 fiscal year (i.e., March 31st, 2012) were excluded from all analyses because previous studies suggest that younger people may have their diabetes managed by a pediatric team, as opposed to FPs (Clement et al., 2018; Panagiotopoulos et al., 2018; Wherrett et al., 2018). In NL specifically, patients are transitioned from pediatric care into adult care at the age of 18 (Williams et al., 2020). Age was tested as a categorical covariate in all analyses.

3.4.2 Enabling Variables

3.4.2.1 Rural Resident. In this study, rurality was defined using census subdivisions and statistical area classification. Statistics Canada provides a variable called statistical area classification type (SAC-type) in which census subdivisions are classified as a census metropolitan area (CMA), census agglomeration (CA), census metropolitan influenced zone (MIZ), or a region with no metropolitan influence.

CMAs and CAs include neighbouring towns where 50% or more of the individuals commute to the urban core of the CMA or CA. An area with Strong MIZ has 30% or more of the workforce who commute to an urban core (Statistics Canada, 2015a). Moderate MIZ is a region where 5% to 29% commute to an urban core, and weak MIZ is where greater than 0% but less than 5% commute to an urban core (Statistics Canada, 2020b). SAC-types are ordered hierarchically, from 1 (within a CMA) to 7 (outside of CMA or CA area having no metropolitan influence). Within Canadian territories, there is an eighth SAC-type, coded as ‘8’, that identifies a census subdivision within the territories that is outside of a CA. For this project, using SAC-type, CMA or CA (codes 1

or 3, respectively[6]) were considered urban, while regions are coded 4-7 were considered rural. These classifications are based on the level of metropolitan influence within the region. In 2016, there were 372 census subdivisions in NL; 35 (9.4%) were classified as urban according to SAC-type, and 337 (90.6%) were classified as rural (Statistics Canada, 2015b).

This classification of rurality differs slightly from the current Statistics Canada urban/rural definition. In 2016, Statistics Canada developed a new operational definition for rurality using population centres. Population centres are regions with more than 1,000 people and a population density greater than 400 persons per square kilometre (Statistics Canada, 2017b). Small (population of 1,000 to 29,999), medium (population of 30,000 to 99,999), and large (population of 100,000 or more) population centres have been delineated within this definition. NL has one large population centre (St. John's) and 27 small population centres with a total population of 301,728 (58.06% of the provincial population).

Classifying rurality using SAC-type is similar to the commonly used Rural and Small Towns (RST) definition. RST defines urban and rural using CMAs and CAs (Bollman, 2016). NL has one CMA and four CAs with a total population of 276,360 (53.18% of the population of NL). SAC-type can add granularity to rurality classification, further classifying rural regions based on their level of metropolitan influence. Additionally, the SAC-type definition of rurality represents the mobility of the workforce, similar to economic zones, making it a good fit for this study (Bollman, 2016).

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[6] There are no regions coded as '2' in NL (CAs with census tracts).

NLCHI provided the 2016 census subdivision code of residence for each patient. Census subdivisions were assigned by NLCHI using a postal code conversion file, which converts the patient's postal code to an alternate level of geography. For this study, the SAC-type for the patient's census subdivision was used to classify their place of residence as urban or rural. Individuals living in a census subdivision with a SAC-type of 1-3 were coded as residing in an urban community (coded as 1). Those living in a census subdivision with a SAC-type of 4-7 were coded as residing in a rural community (coded as 0).

3.4.2.2 Number of Family Physicians per 1,000 People. The number of FPs per 1,000 people is a ratio of the number of FPs practicing in an economic zone to the population (per 1,000 people). This ratio is used to represent the accessibility of FPs within a region. The Canadian Institute for Health Information (2019) estimated that Canada had 241 physicians per 100,000 people in 2018. NL had 270 physicians per 100,000 people, which was the second-highest number of physicians among Canadian provinces and territories. For FPs specifically, the national ratio is 122 FPs per 100,000 population, while NL has a slightly higher ratio of 138 FPs per 100,000 population.

The number of FPs per 1,000 people was calculated using the Physician and Medical Practice Database and the 2016 census population as the denominator. For each year between 2011/12 and 2015/16, the Physician and Medical Practice Database was used to identify the number of FPs practicing within a given economic zone. For each economic zone, the mean number of FPs was calculated for each year from 2011/12 and 2015/16. This average was divided by the census population of the economic zone in 2016 to create a measurement of the number of FPs per 1,000 people. This average was

used to create a categorical variable of three levels: < 1 FP per 1,000 people, 1.0 – 1.25 FPs per 1,000 people, and > 1.25 FPs per 1,000 people.

3.4.2.3 Number of Acute Care Beds per 1,000 People. The number of beds per 1,000 people was calculated as a ratio of the number of acute care beds within the economic zone to the census population of the economic zone. The number of acute care beds was retrieved from the Guide to Canadian Health Care Facilities 2013/2014 (Canadian Healthcare Association, 2014). The year 2013/14 was chosen because it is the median year of data collection and represents the average number of acute care beds in the economic zone between 2011/12 and 2015/16. The number of acute care beds was divided by the 2016 census population for each economic zone to create a ratio of acute care beds per 1,000 population. This average was used to create a categorical variable of four levels: 0 – 1 acute care bed per 1,000 people, > 1 – 2 acute care beds per 1,000 people, > 2 – 3 acute care beds per 1,000 people, and > 3 acute care beds per 1,000 people.

3.4.2.4 Physician Turnover. The primary independent variable for this study was FP turnover. Physician turnover refers to the number of physicians leaving a specific region over a period. Physician turnover is the complementary proportion to physician retention (e.g., turnover = 1 – retention). One study conducted in NL has tested FP retention as a proxy measure of continuity of care and examined the association between retention and avoidable hospital admissions (Knight et al., 2017). This study calculated retention over a five-year period. The benefit of this measure is that it is inclusive of all individuals in the province, as it does not rely on fee-for-service billing data.

Physician turnover was calculated for each fiscal year from 2011/12 to 2015/16. A mean for the five years of study data was calculated using the values from each of these years. A mean score was used because it indicates whether an economic zone had ongoing turnover over the five-year period or had a stable workforce. Physician turnover is represented as a proportion between 0 and 1 (Tepper et al., 2006). A score closer to 1 indicates that more physicians turned over during the five-year period, while a score closer to 0 indicates low turnover. A mean score of 1 would indicate a complete turnover of all physicians in each of the five years (i.e., a turnover score of 1 each of the five years of observation), while a mean turnover score of 0 indicates that none of the physicians turned over in any of the five years of observation. A turnover score cannot be calculated for regions with no FPs, as the numerator and denominator would both be zero. Each patient was assigned a physician turnover score based on their home economic zone. Physician turnover can be calculated using the formula below.

$$\text{Turnover}_{t \text{ to } t+i} = \left[1 - \left(\frac{N_{y,t \cap t+i}}{N_{y,\,t}}\right)\right]$$

Where:

$N_{y,t}$ = number of physicians practicing in an economic zone at time t

$N_{(y,t \cap t+1)}$ = number of physicians practicing in an economic zone at time $t+i$ who are the same individuals as those practicing at time t

Turnover was categorized into four groups: high turnover (> 0.50 - 1.00 turnover score), moderate turnover (> 0.25 - ≤ 0.50 turnover score), low turnover (0.00 – ≤ 0.25), and regions with no FPs. High turnover was coded as 2, moderate turnover coded as 1,

low turnover was coded as 0, and regions with no FPs will be coded as 3. Few studies have examined the frequency of turnover; therefore, appropriate cut points have not been established. Cut points can be developed and tested based on two criteria: 1) by sample size (e.g., tertiles, quartiles); or 2) based on meaningful differences between cut points (e.g., interpretable differences). Tertiles and quartiles were tested, but these cut points did not identify any meaningful differences between turnover groups (e.g., no significant differences between groups on outcomes of interest). These population-based cut-points (e.g., tertiles, quartiles) were skewed because of the disproportionate number of people who lived in the St. John's economic zone. Cut points based on the level of turnover were tested. The values were chosen based on their ability to distinguish differences between groups on the outcomes of interest and their ease of interpretability (e.g., policy relevance).

3.4.3 Need Variables

3.4.3.1 Low-density Lipoprotein Cholesterol. Blood lipid profiles are used to determine a person's level of dyslipidemia and their corresponding risk for cardiovascular disease. For patients with diabetes, an important component of their lipid profile is their level of LDL-C. As an individual's level of LDL-C increases, so does their risk of developing cardiovascular disease (Mancini et al., 2018). The risk of developing cardiovascular disease is even greater among patients with diabetes. The combination of high LDL-C and hyperglycemia can lead to the glycation of the LDL-C particles, increasing the likelihood that the LDL-C particles stick to arterial walls (Mancini et al., 2018). Because of this increased risk, Diabetes Canada recommends that LDL-C levels among patients with diabetes are kept at a lower level than the general population. The

target for patients with diabetes is <2.0 mmol/L, whereas the target for the general population is < 3.5 mmol/L.

For this study, LDL-C test results were used as a covariate representing patient need. A dichotomous variable was created indicating whether the patients' mean LDL-C level met the Diabetes Canada Clinical Practice Guideline recommendation. A mean value was calculated using all the patient's LDL-C test values between 2011/12 and 2015/16. Patients with a mean LDL-C level of <2.0 mmol/L received a code of 1, indicating that their LDL-C level was on-target. If their mean LDL-C level was ≥2.0 mmol/L, they received a code of 0, indicating that their LDL-C level was off-target. Patients without any test values between 2011/12 and 2015/16 were also coded as 0, indicating that they were off-target.

The Diabetes Canada Clinical Practice Guidelines were used to develop the categories used for laboratory testing. The Guidelines recommend that individuals with diabetes receive at least one LDL-C test annually (Mancini et al., 2013, 2018). The Diabetes Canada Clinical Practice Guidelines were updated in 2018, but this update did not change recommendations related to LDL-C levels or testing frequency. Individuals who did not receive any tests over a five-year period are not receiving care that matches the recommendations made within the Guidelines. Individuals above the 2.0 mmol/L are considered to be off-target with poorly managed cholesterol. I also posit that individuals who did not receive any LDL-C tests are poorly managed; therefore, I have used the same code for individuals who are off target and individuals who did not receive any testing.

3.4.3.2 Urine Albumin-to-Creatinine Ratio. UACR is used to screen for albuminuria. Ongoing albuminuria (high albumin levels in the blood) among people with

diabetes can represent early kidney disease or damage (nephropathy). UACR values increase as albuminuria worsens, indicating a progression toward overt kidney disease (McFarlane et al., 2018). Diabetes Canada has set the target for UACR at <2.0 mg/mmol (McFarlane et al., 2018). Using patient data, a median UACR value was calculated using all test results from the study period.

For this study, median UACR was used as a covariate indicating kidney function. A dichotomous variable was created that indicated whether the patients' median UACR met the level recommended by Diabetes Canada. Patients with a median UACR level of <2.0 mg/mmol received a code of 1, indicating that their UACR level was on-target. If their median UACR level was ≥2.0 mg/mmol, they received a code of 0, indicating their UACR level was off-target. If the patient did not have any tests between 2011/12 and 2015/16, they were also coded as 0, indicating that they were off-target.

The Diabetes Canada Clinical Practice Guidelines were used to develop the categories used for laboratory testing. The Guidelines recommend that individuals with diabetes receive at least one UACR test annually due to the high risk of renal disease among people with diabetes (McFarlane et al., 2013, 2018). The Diabetes Canada Clinical Practice Guidelines were updated in 2018, but this update did not change recommendations related to UACR levels or testing frequency. Individuals who did not receive any tests over a five-year period are not receiving care that matches the recommendations made within the Guidelines. UACR levels above the 2.0 mg/mmol are considered to be off-target, and patients above this threshold are at risk of developing kidney disease. I also posit that individuals who did not receive any UACR tests are

poorly managed; therefore, I have used the same code for individuals who are off target and individuals who did not receive any testing.

3.4.4. Outcome Variables

The primary independent variable of physician turnover was chosen because evidence has suggested that it may act as a proxy of continuity of care, which can be used in regions without physician billing data; therefore, this measure is inclusive of the entire population of NL. Given this, it is important that the outcome variables are also measured in a way that is inclusive of all people with diabetes in NL. The outcomes of this study were glycemic control, hospitalization, and mortality. These variables are collected for all patients across the province and available through provincial databases. Through the use of these outcome variables, this study shows how physician turnover affects individuals with diabetes across the province using population-based data sources representative of the NL population.

3.4.4.1 Process of Care. The Diabetes Canada Clinical Practice Guidelines outline the recommended care process for patients with diabetes. Within these guidelines, it is recommended that patients with diabetes receive HbA_{1c} testing at least every six months, even among adults who are consistently achieving glycemic targets (Berard et al., 2013, 2018). Additionally, patients with diabetes should receive lipid profile testing annually, which includes LDL-C (Mancini et al., 2018), as well as an annual UACR test (McFarlane et al., 2018).

For each test type (HbA_{1c}, LDL-C, UACR), a variable of three levels was created to indicate the frequency of testing. For HbA_{1c}, if an individual received two or more tests annually between 2011/12 and 2015/16, this variable was coded as 1, indicating their

testing frequency met the recommendations made by Diabetes Canada. If they received at least one test but did not receive two tests every year, they received a code of 0, indicating that they received some tests, but not frequently enough to meet guideline recommendations. If the individual received zero HbA_{1c} tests between 2011/12 to 2015/16, they received a code of 2, indicating that no testing was performed over the observation period.

For both LDL-C and UACR, if the patient received one or more tests every year from 2011/12 to 2015/16, this variable was coded as 1. If the patient received at least one test but not on an annual basis, the variable was coded as 0. If the individual received zero LDL-C or UACR tests between 2011/12 to 2015/16, they received a code of 2, indicating that no testing was performed over the observation period. LDL-C level and frequency of testing have been used in other studies as a measure of good diabetes management and appropriate care (Gregg et al., 2001; Harris et al., 2006).

3.4.4.2 Glycemic Control. Glycemic control is the maintenance of blood glucose levels, specifically, maintaining those levels at or below specified targets. Blood glucose levels can be measured using glycated hemoglobin (HbA_{1c}) testing. HbA_{1c} represents an average of blood glucose levels over the previous 90 days, although it is more representative of the previous 30 days (Imran et al., 2018). Diabetes Canada has established a target of 7.0% glycated hemoglobin for most patients with diabetes (Imran et al., 2018).

Glycemic control is a key indicator of diabetes management. It was examined as an outcome to indicate whether individuals had good glycemic control, thereby indicating good diabetes management. This variable was also tested as a covariate in the analysis of

process of care, hospitalization, and mortality. Whether individuals met or did not meet glycemic control targets was calculated based on Diabetes Canada Clinical Practice Guidelines (Imran et al., 2018). For each patient, their mean HbA_{1c} value from 2011/12 to 2015/16 was calculated. Mean HbA_{1c} has been suggested to be a stronger predictor of diabetes complications than the baseline value or the last value measured (Lind et al., 2008). A patient with a mean HbA_{1c} value of $\leq 7.0\%$ received a code of 1, indicating their glycemic control was on-target, according to Diabetes Canada Clinical Practice Guideline recommendations. A patient with a mean HbA_{1c} value of $> 7.0\%$ received a code of 0, indicating that their glycemic control did not meet the Diabetes Canada Clinical Practice Guideline recommendations. Finally, patients who did not receive any HbA_{1c} tests between 2011/12 to 2015/16 received a code of 0, indicating their glycemic control was off-target.

The Diabetes Canada Clinical Practice Guidelines were used to develop the categories used for laboratory testing. The Guidelines recommend that individuals with diabetes receive an HbA_{1c} test at least once every six months (Berard et al., 2013, 2018). The Diabetes Canada Clinical Practice Guidelines were updated in 2018, but this update did not change recommendations related to HbA1c levels or testing frequency. Individuals who did not receive any HbA_{1c} tests over a five-year period are not receiving care that matches the recommendations made within the Guidelines; thus, I posit that individuals who did not receive any HbA_{1c} tests are poorly managed and have used the same code for individuals who are off target and individuals who did not receive any testing.

Glycated hemoglobin (HbA_{1c}) was tested as a covariate in analyses for the other outcomes (i.e., process of care, hospitalization, mortality). High levels of HbA_{1c} can lead to microvascular and cardiovascular complications; therefore, it was expected that individuals who did not meet the Diabetes Canada Clinical Practice Guideline HbA_{1c} target would have experienced a higher rate of hospitalization and mortality.

3.4.4.3 Hospitalization. For this study, only inpatient (acute care) hospitalizations were included and analyzed. The PDAD captures other types of care, such as surgical day care and chronic care, but these were identified and excluded from the analyses.

Hospitalization data are submitted to the PDAD following the separation of the patient from the facility (i.e., discharge, transfer, death). Because data are not submitted until the time of separation, the data are organized based on the discharge date. For this study, a hospitalization was defined as a patient being discharged from an acute care facility between 2011/12 and 2015/16. A variable was created to identify those who were hospitalized during this period. Individuals hospitalized between 2011/12 and 2015/16 received a code of 1, and those who were not hospitalized received a code of 0.

3.4.4.4 Mortality. The outcome of mortality indicates whether the patient died between 2011/12 and 2015/16. NLCHI provided the fiscal year of the patient's death within the Chronic Disease Registry. If a patient had a year of death between 2011/12 and 2015/16, they were coded as 1, indicating that they died during the study years. Otherwise, they received a code of 0, indicating that they lived.

3.5 Data Preparation

Data preparation and analyses were performed using Statistical Package for the Social Sciences (SPSS) version 25 for Windows and R version 4.0.2 (R Core Team, 2020) with package stddiff (Du & Hao, 2019).

3.5.1 Data Cleaning

3.5.1.1 Assessment of Missing Data. Using SPSS (version 25), frequency and descriptive analyses were performed to identify and analyze missing data. Patients missing sex, age, or census subdivision were excluded from the analyses. Patients with values for demographic variables outside of the valid range were removed (e.g., age below 0 years). Census subdivision entries were checked against a list of census subdivisions from Statistics Canada to ensure all entries were valid.

For laboratory data, tests were excluded if the values were missing, if values were above or below the expected range, if a non-numeric value was entered as the test result, or if an entry was duplicated (matching test result with matching date for the same individual). Results for HbA_{1c}, LDL-C, and UACR should be positive, continuous values. HbA_{1c} should range between 2.5% - 16.0% (DiaSys Diagnostic Systems GmbH & Company, 2012; Heinemann & Freckmann, 2015). LDL-C should range between 0.0 mmol/L – 3.40 mmol/L (Calgary Laboratory Services, 2019). UACR can be as low as zero mg/mmol without an upper limit.

For HbA_{1c} tests, before linking to the sample, 42,972 tests were excluded (8.8%). Most of the exclusions were due to missing data (n = 19,484; 4.0%) or duplicated entry (n = 20,146; 4.1%). For LDL-C tests, before linking to the sample, 21,373 tests were excluded (5.7%). Most of the exclusions were due to missing data (n = 11,344; 3.0%) or duplicated entry (n = 9,975; 2.7%). For UACR tests, before linking to the sample, 28,483

tests were excluded (16.9%). Most of the exclusions were due to missing data (n = 25,302; 15.0%) or duplicated entry (n = 2,626; 1.6%).

3.6 Analysis

Descriptive analyses of the sample characteristics (frequency, mean, standard deviation) were performed and reported for all variables. Chi-square (χ^2) and Fisher's exact tests were used to assess each outcome and predictor variables. Standardized differences were calculated for each bivariate comparison to determine the magnitude of difference between groups. Standardized difference was developed by Dr. Peter Austin to compare the frequency of a dichotomous variable between two groups independent of sample size (P. C. Austin, 2009a, 2009b).

3.6.1 Multivariate Logistic Regression

For this study, glycemic control, hospitalization, mortality, and process of care were analyzed using multivariate logistic regression. Logistic regression is used to analyze a dichotomous dependent variable and provides odds ratios as the output. Glycemic control, hospitalization, mortality, and process of care are dichotomous outcomes ([on-target/off-target]/ [was hospitalized/was not hospitalized]/[died/lived]). The levels of physician turnover – high, moderate, low, no FPs – were used as the grouping variable for these analyses. Multivariate logistic regression is an extension of logistic regression where two or more independent variables are added to the analysis as predictors of the dependent variable. Log odds can be calculated using the following equation:

$$log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_{age}X_{age} + \beta_{sex}X_{sex} + \beta_{rural}X_{rural} \ldots + \beta_i X_i$$

where *log(p/1-p)* is the log odds of the outcome and β_i is the regression coefficient value for the variable X_i.

3.6.2 Variable Selection

For multivariate logistic regressions, variables were tested in univariate (unadjusted) regression analyses and significant variables (where $p < 0.25$) were tested in the regression model (Hosmer & Lemeshow, 2000). Based on initial results from bivariate tests, age-sex interactions were also tested in the regression model. To select predictor variables to retain in the model, Wald χ^2 test (Wald test) and reductions in -2-log likelihood ratio were used. The Wald test is used to determine whether the relationship between the predictor and outcome variable is greater than zero. If the p-value of the Wald test is less than the predefined alpha of .05, then the predictor has a significant, non-zero relationship with the outcome. The -2-log likelihood ratio is used to compare two models to determine whether one model fits the data better than the previous model, following the addition of predictors. The difference in -2-log likelihood scores between two models can be calculated and used as a χ^2 statistic. Using the degrees of freedom from the most current model, significance can be tested. A p-value lower than .05 (the preset alpha) indicates that the model is a significant improvement. The Wald test and -2-log likelihood statistics are used to test the model as variables are added. Variables with a significant Wald test value and that improve the -2-log likelihood were included in the final model. Once the significant independent variables were identified, the primary independent variable, physician turnover, was entered into the model. This is done to determine its unique contribution after controlling for other significant relationships (Tabachnick & Fidell, 2012).

To assess the model's predictive power and goodness of fit, Nagelkerke's r^2 and Hosmer & Lemeshow tests were used. Nagelkerke's r^2 is used to determine how much variation the model explains (Nagelkerke, 1991). Nagelkerke's r^2 is a corrected version of Cox and Snell's r^2 that ranges from 0 to 1 (IBM, 2017). An r^2 of 1 indicates that the model perfectly explains variation, while an r^2 of 0 indicates that the model does not explain any of the variation. Hosmer & Lemeshow test was used to test the goodness of fit of a model. Hosmer & Lemeshow compares predicted outcomes (based on the model) to observed outcomes. A p-value ≥ 0.05 means there is no difference between observed and expected outcomes, suggesting that the model is a good fit.

3.6.3 Sample Size Justifications

After excluding individuals who moved between 2011/12 and 2015/16, individuals who were missing necessary data, or individuals who were diagnosed with diabetes according to the CCDSS case definition alone, an a priori analysis of the data set estimated that the sample will consist of approximately 35,000 individuals with diabetes during the study period (2011/12-2015/16).

When examining the outcome variables, studies have estimated that between 50%-65% of patients with diabetes have inadequate glycemic control (Harris et al., 2005, 2006; Public Health Agency of Canada, 2011a). Previous studies have examined the rate of hospitalization among people with diabetes. The hospitalization rates range from between 136.8 hospitalizations per 1,000 individuals for a one-year period to 248.8 hospitalizations per year per 1,000 individuals for a ten-year period (Lukewich et al., 2020; Roche & Wang, 2013). This study examines hospitalizations over a five-year period, so it can be expected that the hospitalization rate for this study will fall between

these values, at approximately 192.8 hospitalizations per year per 1,000 individuals. At this rate, it would be expected that 23,005 individuals (65.7% of the sample) would be hospitalized for any reason over a five-year period. Finally, previous studies have shown mortality rates among people with diabetes to fall between 245.4 to 264.75 deaths per 10,000 individuals (Lipscombe et al., 2010; Roche & Wang, 2013). Assuming there are 245.4 deaths per 10,000 individuals annually, this would suggest that 4089 (11.7%) of the sample of 35,000 people will have died between 2011/12 and 2015/16.

Assuming a sample of 35,000 individuals, this study is adequately powered (power of 80%; alpha of 5%) to detect a significant difference between high and low physician turnover groups for the outcomes of glycemic control, hospitalization, and mortality at 1.5%, 1.42%, and 0.98% respectively. In addition to statistical significance, standardized differences will be examined to determine whether the differences between groups are meaningful.

3.7 Research Ethics

Approvals for the project were received from the Newfoundland and Labrador Health Regional Ethics Board (HREB; file #20201457) and the Secondary Uses Committee of NLCHI (reference #IM188870). Appendices B and C contain the approval letters from HREB and NLCHI, respectively. As necessary, to ensure the privacy of patients, any sub-region or aggregate with fewer than five patients was merged to an adjacent sub-region or aggregate. This process is widely used to prevent the re-identification of patients through spatially referenced data (NCHS Research Data Center, 2012).

Chapter 4: Results

4.1 Descriptive Statistics

There were 79,047 individuals with type 1 and type 2 diabetes obtained from the Newfoundland and Labrador Chronic Disease Registry as of March 31, 2016. Only individuals diagnosed according to the laboratory definition or both the laboratory and CCDSS definition of diabetes were included in the sample. Figure 4.1 shows the flow chart of inclusion and exclusion criteria. Individuals who were missing data for the variables case year (n = 26; 0.03% of the population of people with diabetes), place of residence (n = 2,590; 3.3% of the population of people with diabetes), sex (n = 134; 0.17% of the population of people with diabetes), and age (n = 6; 0.01% of the population of people with diabetes) were excluded from all analyses, leaving 76,261 cases with complete data. For this study, incident cases, that is, cases diagnosed between 2011/12 and 2015/16 (n = 25,864; 32.7% of the population of people with diabetes), were excluded, leaving 50,427 prevalent cases of diabetes. Incident cases were excluded because they did not have complete data for all five years of the study period, given that they were newly added to the database during the study period. Individuals who moved between economic zones between 2011/12 and 2015/16 (n = 2,113; 2.7% of the population of people with diabetes) and those who moved in or out of the province between 2011/12 and 2015/16 (n = 594; 0.75% of the population of people with diabetes) were excluded from the analyses, leaving 47,720 individuals who lived in the province for the duration of the study period. Individuals identified as having diabetes by CCDSS definition alone (n = 8,664; 11.0% of the population of people with diabetes) were

excluded from the sample. Finally, individuals younger than 20 years old as of March 31st, 2012 were excluded (n = 359; 0.45% of the population of people with diabetes).

Two sensitivity analyses were conducted to examine the characteristics of individuals who were excluded because they moved economic zone (Appendix E) and individuals who were excluded because they were identified as having diabetes by the CCDSS case definition alone (Appendix F). The sensitivity analysis in Appendix E was performed to compare individuals who did and did not move economic zones during the study period to determine whether individuals who moved during the study period were sicker than those who did not move. These analyses found that there was no statistically significant difference in the proportion of individuals meeting glycemic control targets between those who did and did not move economic zones, while a greater proportion of individuals who moved economic zones were hospitalized (n = 858; 50.9%) and a smaller proportion died (n = 151; 9.0%), as compared to individuals who did not move (n = 17,710; 45.8% and n = 5,213; 13.5%, respectively). These sensitivity analyses suggest that individuals who moved within the province were more likely to have been hospitalized; therefore, some sicker individuals may have been excluded. The analysis in Appendix F was performed to determine whether the individuals excluded based on case definition differed significantly from the sample used for analyses. The results of these sensitivity analyses suggest that the CCDSS-only group significantly differed from the combined case definition group, particularly in age, mortality, and testing levels and frequencies. The testing patterns among the CCDSS-only group were substantially different from the study sample, suggesting that the CCDSS-only group is markedly different from the sample and the exclusion is appropriate. I posit that there may be a high

proportion of long-term care residents in this group, although using the available data, this cannot be determined for certain.

Table 4.1 describes the characteristics of the sample. The sample included 38,697 individuals: 50.1% female (n = 19,390). Most individuals were aged 65-79 years (n = 17,139; 44.3%) or 50-64 years (n = 11,077; 28.6%). A greater proportion of the patients in the sample resided in a rural census subdivision (n = 21,771; 56.1%) than an urban census subdivision (n = 16,986; 43.9%). Nearly half of the population (n = 18,221; 47.1%) lived in an economic zone with more than 1.25 family physicians (FPs) per 1,000 population. The largest proportion of the sample lived in an economic zone with low (n = 15,962; 41.2%) or moderate (n = 21,189; 54.8%) turnover of FPs, while only 3.4% (n = 1,297) and 0.6% (n = 249) lived in an economic zone with high turnover or with no FPs, respectively. Nearly half of the sample lived in an economic zone with three or more acute care beds per 1,000 population (n = 18,242; 47.1%).

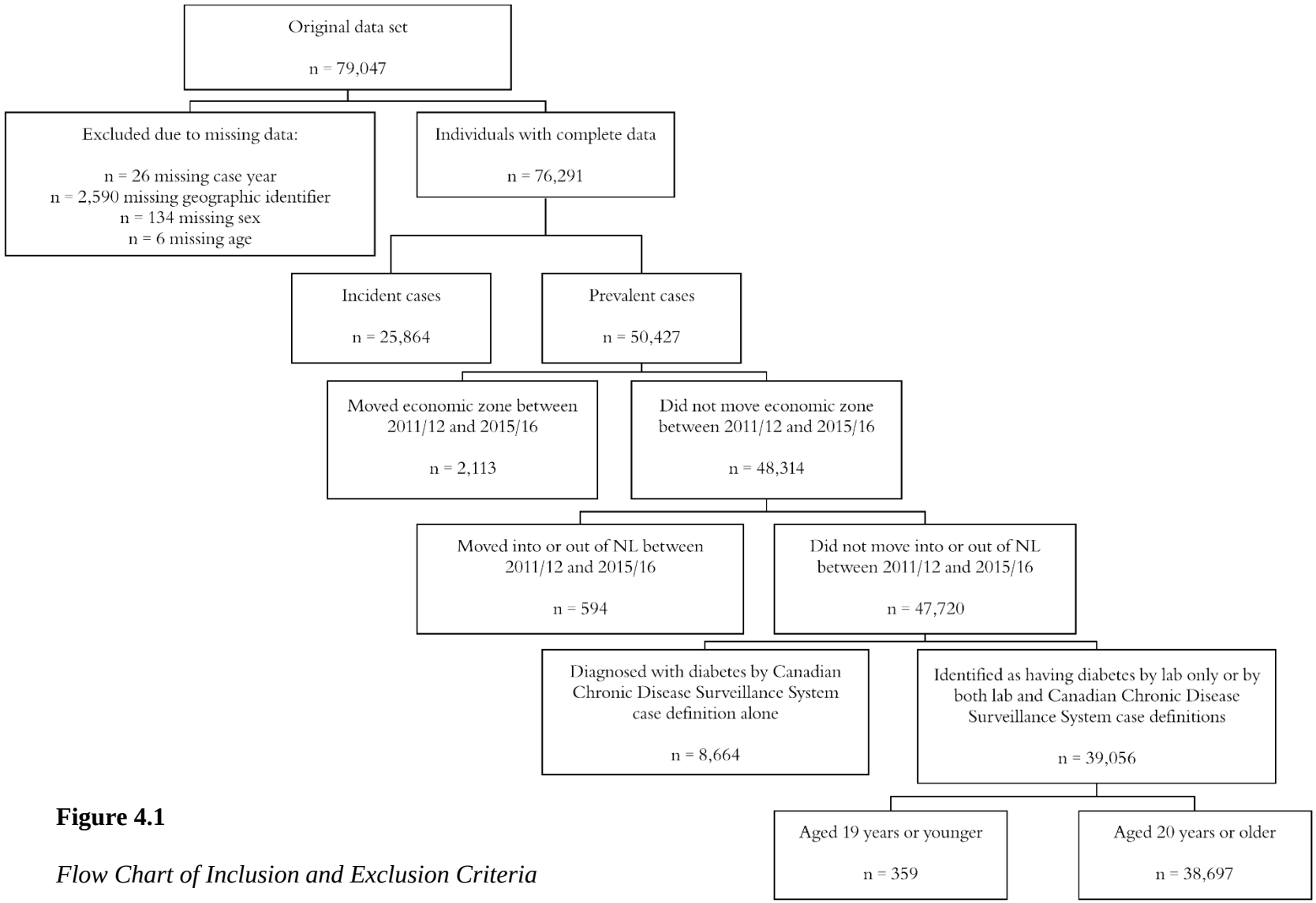

Figure 4.1

Flow Chart of Inclusion and Exclusion Criteria

Table 4.1

Characteristics of Adults with Diabetes in Newfoundland and Labrador (n = 38,697)

Variable	n (%)
TOTAL	**38,697 (100.0)**
Predisposing factors	
Sex	
Female	19,390 (50.1)
Male	19,307 (49.9)
Age (years)	
20-34	550 (1.4)
35-49	2,814 (7.3)
50-64	11,077 (28.6)
65-79	17,139 (44.3)
80+	7,117 (18.4)
Enabling factors	
Rurality	
Rural	21,771 (56.1)
Urban	16,986 (43.9)
Number of FPs per 1,000 pop.	
<1.0	5,596 (14.5)
1.0-1.25	14,880 (38.5)
>1.25	18,221 (47.1)
Physician turnover	
Low (0-≤25)	15,962 (41.2)
Moderate (>25-≤50)	21,189 (54.8)
High (>50-100)	1,297 (3.4)
No FPs in EZ	249 (0.6)
Acute care beds per 1,000 population	
0-1 bed	2,608 (6.7)
> 1-2 beds	4,562 (11.8)
> 2-3 beds	13,285 (34.3)
3+ beds	18,242 (47.1)
Need factors	
HbA1c mean level*	
Did not meet CPG	27,437 (70.9)
Met CPG	11,260 (29.1)
LDL-C mean*	
Did not meet CPG	24,486 (63.3)
Met CPG	14,211 (36.7)
UACR median*	
Did not meet CPG	24,175 (62.5)
Met CPG	14,522 (37.5)
Process variables	
HbA1c testing frequency	
Did not meet CPG	31,061 (80.3)
Met CPG	6,186 (16.0)
Did not receive any tests	1,450 (3.7)
LDL-C testing frequency	
Did not meet CPG	23,202 (60.0)
Met CPG	12,590 (32.5)
Did not receive any tests	2,905 (7.5)
UACR testing frequency	
Did not meet CPG	23,274 (60.1)
Met CPG	3,212 (8.3)
Did not receive any tests	12,211 (31.6)
Outcomes	
Glycemic control*	
Off-target	27,437 (70.9)
On-target	11,260 (29.1)
Hospitalization	
Was hospitalized	17,710 (45.8)
Was not hospitalized	20,987 (54.2)
Mortality	
Died	5,212 (13.5)
Lived	33,485 (86.5)

FP – family physician; EZ – economic zone; HbA1c – glycated hemoglobin; LDL-C – low-density lipoprotein cholesterol; UACR – urine albumin-to-creatinine ratio; CPG – Clinical Practice Guideline
* - individuals with zero tests are coded as 'did not meet.'

Most patients did not meet Diabetes Canada Clinical Practice Guideline (CPG) recommendations for mean HbA_{1c} level (n = 27,437; 70.9%) or mean low-density lipoprotein cholesterol (LDL-C; n = 24,486; 63.3%), and median urine albumin-to-creatinine ratio (UACR; n = 24,175; 62.5%). Similarly, most patients did not receive the CPG recommendation for frequency of testing for HbA_{1c} (n = 31,061; 80.3%), LDL-C (n = 23,202; 60.0%), or UACR (n = 23,274; 60.1%).

Regarding the outcomes of glycemic control, hospitalization, and mortality, 70.9% of individuals (n = 27,437) did not meet the CPG target for glycemic control (HbA_{1c}), 45.8% of individuals (n = 17,710) were hospitalized, and 13.5% of individuals (n = 5,212) died during the five-year study period.

4.2 Bivariate Analysis by Level of Physician Turnover

Table 4.2 presents a bivariate analysis of level of physician turnover and characteristics of adults with diabetes in NL. Most of the sample lived in an economic zone with low (n = 15,962; 41.2% of the study population) or moderate turnover (n = 21,189; 54.8% of the study population), while 1,297 (3.4% of the study population) individuals lived in an economic zone with high turnover, and 249 (0.6% of the study population) individuals lived in an economic zone with no FPs. Given the unequal sample size between the four turnover groups, inferences about individuals in the no FPs group may be underpowered, due to the small group size. The low turnover group had the highest proportion of males (n = 8,182; 51.3%) and differed from the moderate turnover and the no FPs in the economic zone groups on the proportion of males and females. Individuals living in economic zones with no FPs had a greater proportion of females than the other levels of FP turnover (n = 149; 59.8%) and significantly differed from the moderate turnover group on the proportion of males and females. When examining age, only one

pairwise comparison was significant; the low turnover group differed from the moderate turnover group in proportion of individuals across age groups, as the low FP turnover group had a greater proportion of individuals in the two lowest age groups (20-34, 35-49) and the moderate turnover group had a greater proportion of individuals in the two oldest age groups (65-79, 80+). All groups had different proportions of individuals living in rural and urban regions, except for the high turnover and no FPs in economic zone groups, which consisted only of people living in rural census subdivisions. All groups differed on the number of FPs and the number of acute care beds in the economic zone per 1,000 population. The low turnover group had the greatest proportion of individuals living in an economic zone with more than 1.25 FPs per 1,000 population (n = 15,371; 96.3%) and three or more acute care beds per 1,000 population (n = 15,371; 96.3%). Only the low and moderate turnover groups differed on the proportion of individuals meeting the recommended HbA_{1c} level. The moderate turnover group had the greatest proportion of individuals not meeting the recommended HbA_{1c} level (n = 15,270; 72.1%). The low turnover group differed from the moderate and high turnover group and the no FPs in the economic zone group in the proportion of individuals meeting the recommended LDL-C level. The low turnover group had the greatest proportion of individuals who met the recommended LDL-C level (n = 6,367; 39.9%). Additionally, the moderate and high turnover groups differed on the proportion of individuals meeting the recommended LDL-C level. The high turnover group had the greatest proportion of individuals who did not meet the recommended LDL-C level (n = 946; 72.9%). The moderate turnover group differed from the low and high turnover groups on the proportion of individuals meeting the recommended UACR level. The moderate turnover group had the greatest proportion of individuals not meeting the

Table 4.2

Bivariate Analysis of Level of Turnover and Characteristics of Adults with Diabetes in Newfoundland and Labrador (n = 38,697)

Variable	Low Turnover n (%)	Mod. Turnover n (%)	High Turnover n (%)	No FPs in EZ n (%)	Pairwise comparisons
TOTAL	**15,962 (100.0)**	**21,189 (100.0)**	**1,297 (100.0)**	**249 (100.0)**	
Predisposing factors					
Sex					a, c, e
Female	7,780 (48.7)	10,785 (50.9)	676 (52.1)	149 (59.8)	
Male	8,182 (51.3)	10,404 (49.1)	621 (47.9)	100 (40.2)	
Age (years)					a
20-34	308 (1.9)	225 (1.1)	14 (1.1)	3 (1.2)	
35-49	1,283 (8.0)	1,411 (6.7)	86 (6.6)	34 (13.7)	
50-64	4,726 (29.6)	5,918 (27.9)	337 (26.0)	96 (38.6)	
65-79	6,755 (42.3)	9,712 (45.8)	579 (44.6)	93 (37.3)	
80+	2,890 (18.1)	3,923 (18.5)	281 (21.7)	23 (9.2)	
Enabling factors					
Rurality					a, b, c, d, e
Rural	2,201 (13.8)	17,964 (84.8)	1,297 (100.0)	249 (100.0)	
Urban	13,761 (86.2)	3,225 (15.2)	0 (0.0)	0 (0.0)	
Number of FPs per 1,000 pop.					a, b, c, d, e, f
<1.0	591 (3.7)	4,756 (22.4)	0 (0.0)	249 (100.0)	
1.0-1.25	0 (0.0)	13,710 (64.7)	1,170 (90.2)	0 (0.0)	
>1.25	15,371 (96.3)	2,723 (12.9)	127 (9.8)	0 (0.0)	
Acute care beds per 1,000 population					a, b, c, d, e, f
0-1 beds	0 (0.0)	1,819 (8.6)	540 (41.6)	249 (100.0)	
1-2 beds	596 (3.7)	3,971 (18.7)	0 (0.0)	0 (0.0)	
2-3 beds	0 (0.0)	13,158 (62.1)	127 (9.8)	0 (0.0)	
3+ beds	15,371 (96.3)	2,241 (10.6)	630 (48.6)	0 (0.0)	
Need factors					
HbA1c mean*					a
Did not meet CPG	11,114 (69.6)	15,270 (72.1)	881 (67.9)	172 (69.1)	
Met CPG	4,848 (30.4)	5,919 (27.9)	416 (32.1)	77 (30.9)	
LDL-C mean*					a, b, c, d
Did not meet CPG	9,595 (60.1)	13,764 (65.0)	946 (72.9)	181 (72.7)	
Met CPG	6,367 (39.9)	7,425 (35.0)	351 (27.1)	68 (27.3)	
UACR median*					a, d
Did not meet CPG	9,635 (60.4)	13,640 (64.4)	744 (57.4)	156 (62.7)	
Met CPG	6,327 (39.6)	7,549 (35.6)	553 (42.6)	93 (37.3)	
Process variables					
HbA1c testing frequency					a, b, c, d, e, f
Did not meet CPG	12,675 (79.4)	17,319 (81.7)	925 (71.3)	142 (57.0)	
Met CPG	2,756 (17.3)	3,023 (14.3)	304 (23.4)	103 (41.4)	
Did not receive any tests	531 (3.3)	847 (4.0)	68 (5.2)	4 (1.6)	
LDL-C testing frequency					a, b
Did not meet CPG	9,021 (56.6)	13,204 (62.3)	823 (63.5)	154 (61.8)	
Met CPG	5,848 (36.6)	6,294 (29.7)	360 (27.8)	88 (35.3)	
Did not receive any tests	1,093 (6.8)	1,691 (8.0)	114 (8.8)	7 (2.8)	
UACR testing frequency					a, b, d, f
Did not meet CPG	9,838 (61.6)	12,388 (58.5)	887 (68.4)	161 (64.7)	
Met CPG	1,541 (9.7)	1,574 (7.4)	65 (5.0)	32 (12.9)	
Did not receive any tests	4,583 (28.7)	7,227 (34.1)	345 (26.6)	56 (22.5)	

FP – family physician; EZ – economic zone; HbA1c – glycated hemoglobin; LDL-C – low-density lipoprotein cholesterol; UACR – urine albumin-to-creatinine ratio; CPG – Clinical Practice Guideline

* - individuals with zero tests are coded as 'did not meet.'

a, b, c, d, e, f indicates the results of multiple pairwise comparisons between levels of turnover ($p < 0.05$, Bonferroni correction applied)

a – low and moderate turnover differ
b – low and high turnover differ
c – low turnover and no FPs in EZ differ
d – moderate and high turnover differ
e – moderate turnover and no FPs in EZ differ
f – high turnover and no FPs in EZ differ

recommended UACR level (n = 13,640; 64.4%). All groups differed from each other on the proportion of individuals meeting the recommended HbA_{1c} testing frequency. The low turnover group differed from the moderate and high turnover groups on the proportion of individuals meeting the recommended testing frequency for LDL-C. The low turnover group had the greatest proportion of individuals who met the recommended LDL-C testing frequency (n = 5,848; 36.6%). The low and moderate turnover groups differed on the proportion of individuals meeting the recommended testing frequency for UACR. Additionally, the high turnover group differed from the low and moderate turnover groups and the no FPs in the economic zone group. The high turnover group had the greatest proportion of individuals who did not meet the recommended UACR testing frequency (n = 887; 68.4%).

This bivariate analysis by level of turnover indicated the potential presence of collinearity between covariates, specifically between FP turnover, rurality, and the number of FPs and number of acute care beds per 1,000 population. All variables were tested for potential collinearity. Number of acute care beds and the number of FPs per 1,000 population were highly collinear. Rurality was highly collinear with FP turnover and number of FPs and number of acute care beds per 1,000 population. Rurality and number of FPs per 1,000 population were considered redundant and were excluded from the following regression analysis. The complete collinearity matrix is presented in Appendix G.

4.3 Glycemic Control

Table 4.3 presents a comparison of characteristics between individuals whose mean HbA_{1c} level did not meet the Diabetes Canada CPG target (off-target) and individuals who met the guideline recommendation (on-target). Overall, 27,437 (70.9% of the study sample)

Table 4.3

Bivariate Analysis of Glycemic Control and Characteristics of Adults with Diabetes in Newfoundland and Labrador (n = 38,697)

Variable	Off-target n (%)	On-target n (%)	p-value	Standard difference (95% CI)
TOTAL	**27, 437(100.0)**	**11,260 (100.0)**		
Predisposing factors				
Sex			0.015	0.027 (0.005 – 0.049)
Female	13.639 (49.7)	5,751 (51.1)		
Male	13,798 (50.3)	5,509 (48.9)		
Age (years)			< 0.0001	0.314 (0.292 – 0.336)
20-34	473 (1.7)	77 (0.7)		
35-49	2,318 (8.4)	496 (4.4)		
50-64	8,544 (31.1)	2,533 (22.5)		
65-79	11,595 (42.3)	5,544 (49.2)		
80+	4,507 (16.4)	2,610 (23.2)		
Enabling factors				
Rurality			< 0.001	0.041 (0.019 – 0.063)
Rural	15,555 (56.7)	6,156 (54.7)		
Urban	11,882 (43.3)	5,104 (45.3)		
Number of FPs per 1,000 pop.			< 0.001	0.046 (0.024 – 0.068)
<1.0	4,075 (14.9)	1,521 (13.5)		
1.0-1.25	10,596 (38.6)	4,284 (38.0)		
>1.25	12,766 (46.5)	5,455 (48.4)		
Physician turnover			< 0.0001	0.064 (0.042 – 0.086)
Low (0-≤25)	11,114 (40.5)	4,848 (43.1)		
Moderate (>25-≤50)	15,270 (55.7)	5,919 (52.6)		
High (>50-100)	881 (3.2)	416 (3.7)		
No FPs in EZ	172 (0.6)	77 (0.7)		
Acute care beds per 1,000 population			< 0.0001	0.070 (0.048 – 0.092)
0-1 beds	1,962 (7.2)	646 (5.7)		
> 1-2 beds	3,239 (11.8)	1,323 (11.7)		
> 2-3 beds	9,509 (34.7)	3,776 (33.5)		
3+	12,727 (46.4)	5,515 (49.0)		
Need factors				
LDL-C mean*			0.924	0.001 (-0.021 – 0.023)
Did not meet CPG	17,357 (63.3)	7,129 (63.3)		
Met CPG	10,080 (36.7)	4,131 (36.7)		
UACR median*			< 0.0001	0.063 (0.041 – 0.085)
Did not meet CPG	17,384 (63.4)	6,791 (60.3)		
Met CPG	10,053 (36.6)	4,469 (39.7)		
Process variables				
HbA1c testing frequency			< 0.0001	0.346 (0.324 – 0.368)
Did not meet CPG	21,420 (78.1)	9,641 (85.6)		
Met CPG	4,567 (16.6)	1,619 (14.4)		
Did not receive any tests	1,450 (5.3)	0 (0.0)		
LDL-C testing frequency			< 0.0001	0.211 (0.189 – 0.233)
Did not meet CPG	16,773 (61.1)	6,429 (57.1)		
Met CPG	8,292 (30.2)	4,298 (38.2)		
Did not receive any tests	2,372 (8.6)	533 (4.7)		
UACR testing frequency			< 0.0001	0.144 (0.122 – 0.166)
Did not meet CPG	16,891 (61.6)	6,383 (56.7)		
Met CPG	2,411 (8.8)	801 (7.1)		
Did not receive any tests	8,135 (29.6)	4,076 (36.2)		

CI – confidence interval; FP – family physician; EZ – economic zone; HbA1c – glycated hemoglobin; LDL-C – low-density lipoprotein cholesterol; UACR – urine albumin-to-creatinine ratio; CPG – Clinical Practice Guideline
* - individuals with zero tests are coded as 'did not meet.'

individuals had a mean HbA_{1c} that was off-target. A greater proportion of individuals who were off-target were male (n = 13,639; 50.3%) and living in rural regions (n = 15,555; 56.7%), as compared to individuals who were on-target (n = 5,509, 48.9% and 6,156; 54.7%, respectively). A greater proportion of individuals who were off-target were in the 20-34 (n = 473; 1.7%) and 35-49 (n = 2,318; 8.4%) year old age groups, as compared to individuals who were on-target (n = 77, 0.7%; n = 496, 4.4% respectively). A greater proportion of individuals who were off-target resided in an economic zone with less than one FP per 1,000 population (n = 4,075; 14.9%) and less than one acute care bed per 1,000 population (n = 1,962; 7.2%), as compared to individuals who were on-target (n = 1,521; 13.5% and n = 646; 5.7% respectively). A greater proportion of individuals who were off-target lived in an economic zone with moderate FP turnover (n = 15,270; 55.7%) as compared to individuals who were on-target (n =5,919; 52.6%). There was no difference in the proportion of individuals who were off- and on-target for HbA_{1c} levels who were meeting the CPG recommended target for mean LDL-C (n = 17,357; 63.3% vs. n = 7,129; 63.3%). A greater proportion of individuals who were off-target for HbA_{1c} were also off-target for median UACR (n = 17,384; 63.4%), as compared to individuals who were on-target for HbA_{1c} (n = 6,791; 60.3%). In terms of frequency of testing, a greater proportion of individuals who were off-target for glycemic control met the CPG recommendation for frequency of HbA_{1c} (n = 4,567; 16.6%) and UACR testing (n = 2,411; 8.8%), as compared to individuals whose mean HbA_{1c} was on-target (n = 1,619; 14.4% and n = 801; 7.1%, respectively). Conversely, a lower proportion of individuals whose mean HbA_{1c} was off-target met the CPG recommendations for LDL-C frequency of testing (n = 8,292; 30.2%) compared to individuals with on-target mean HbA_{1c} (n = 4,298; 38.2%).

The standardized difference quantifies the magnitude of the difference in proportions between groups (P. C. Austin, 2009a; Yang & Dalton, 2012). For most comparisons between individuals meeting and not meeting the recommended glycemic control level, the standardized difference was low (< 0.1), suggesting that the difference, regardless of statistical significance, is minimal. The variables with a larger magnitude of difference (e.g., more meaningful difference) included age group (0.314), HbA_{1c} (0.346), LDL-C (0.211), and UACR (0.144) testing frequency.

4.3.1 Multivariable Logistic Regression of Predictors of Glycemic Control

Table 4.4 shows the results of the multivariable binomial logistic regression predicting the likelihood of meeting the recommended target for HbA_{1c} level while controlling for other covariates. Turnover was associated with glycemic control. Individuals living in an economic zone with moderate turnover were less likely to have met the target HbA_{1c} level (OR = 0.875; 95% CI 0.805 - 0.952) compared to individuals living in an economic zone with low turnover. Conversely, individuals living in an economic zone with no FPs were more likely (OR = 1.477; 95% CI 1.095 - 1.993) to meet the target HbA_{1c} level compared to individuals living in an economic zone with low turnover. Individuals living in regions with high FP turnover did not significantly differ from individuals living in regions with low FP turnover in their likelihood of meeting glycemic control targets. The interaction between age and sex suggests that all age groups of males and females older than 49 years (50-64, 65-79, 80+) were more likely to meet glycemic control targets than females aged 20-34. Males aged 20-34 were less likely to meet glycemic control targets than females aged 20-34 (OR = 0.536, 95% CI 0.326 – 0.879). Individuals meeting the target level for UACR were more likely to meet the HbA_{1c} target (OR =

1.274; 95% CI 1.216 - 1.336). Finally, all groups with more than one acute care bed per 1,000 (1-2, 2-3, 3+ beds per 1,000 population) were more likely to meet glycemic control targets.

Table 4.4

Predictors of Meeting Recommended HbA1c Level among Adults with Diabetes in Newfoundland and Labrador (n = 38,697)

	β	Standard error	Wald Chi-square	df	p-value	Odds ratio	Odds ratio 95% CI
Constant	-1.875	0.172	119.367	1	< 0.0001	0.153	
Sex							
Female						1.00	
Male	-0.624	0.253	6.089	1	0.014	0.536	(0.326 – 0.879)
Age (years)							
20-34						1.00	
35-49	0.152	0.173	0.774	1	0.379	1.164	(0.830 – 1.633)
50-64	0.380	0.163	5.445	1	0.020	1.462	(1.063 – 2.012)
65-79	0.852	0.161	27.903	1	< 0.0001	2.345	(1.709 – 3.216)
80+	1.100	0.163	45.552	1	< 0.0001	3.005	(2.183 – 4.136)
Age*Sex							
Male*35-49	0.334	0.272	1.506	1	0.220	1.396	(0.819 – 2.380)
Male*50-64	0.584	0.257	5.172	1	0.023	1.794	(1.084 – 2.969)
Male*65-79	0.646	0.255	6.422	1	0.011	1.909	(1.158 – 3.147)
Male*80+	0.617	0.258	5.720	1	0.017	1.853	(1.118 – 3.071)
Number of acute care beds per 1,000 pop.							
0 - 1 bed						1.00	
> 1 - 2 beds	0.305	0.061	25.082	1	< 0.0001	1.357	(1.204 - 1.529)
> 2 - 3 beds	0.265	0.055	23.332	1	< 0.0001	1.303	(1.170 - 1.451)
3+	0.255	0.062	17.019	1	< 0.0001	1.291	(1.143 - 1.457)
Median UACR value*							
Did not meet CPG						1.00	
Met CPG	0.242	0.024	102.840	1	< 0.0001	1.274	(1.216 - 1.336)
Turnover							
Low turnover						1.00	
Moderate turnover	-0.133	0.043	9.664	1	0.002	0.875	(0.805 - 0.952)
High turnover	0.128	0.068	3.556	1	0.059	1.137	(0.995 - 1.298)
No FPs in EZ	0.390	0.153	6.513	1	0.011	1.477	(1.095 – 1.993)

df – degrees of freedom; OR – odds ratio; CI – confidence interval; HbA1c – glycated hemoglobin; UACR – urine albumin-to-creatinine ratio; CPF – Clinical Practice Guideline; FP – family physician; EZ – economic zone
* individuals with zero tests are coded as 'did not meet.'

This model was statistically significant ($\chi^2(16) = 958.812$, $p < 0.0001$), passed the Hosmer Lemeshow test ($p > 0.05$), and explained 3.5% of the variance in glycemic control (Nagelkerke R^2). Residuals were examined. Eighty-seven cases (0.22%) had a standard deviation greater than two. Cook's distance was calculated for all cases. No cases had a value greater than one, suggesting that no cases had an undue influence on the model; therefore, all cases were retained in the analysis.

4.4 Hospitalization

Table 4.5 compares the characteristics of individuals who were not hospitalized (n = 20,987; 54.2% of the study sample) to individuals who were hospitalized (n = 17,710; 45.8% of the study sample). A significantly greater proportion of individuals who were not hospitalized were male (n = 10,568; 50.4%) and living in an urban community (n = 9,318; 44.4%), as compared to individuals who were hospitalized (n = 8,739; 49.3% and n = 7,668; 43.3%). Individuals who were not hospitalized were younger, with a greater proportion of 20-34 (n = 330; 1.6%), 35-49 (n = 1,928; 9.2%), and 50-64 (7,213; 34.4%) year olds, as compared to individuals who were hospitalized (n = 220, 1.2%; n = 886, 5.0%; n = 3,864, 21.8%, respectively). There were no differences in the number of FPs or the number of acute care beds within the economic zones of those who were hospitalized and those who were not. A greater proportion of hospitalized individuals lived in an economic zone with high physician turnover (n = 709; 4.0%) compared to individuals who were not hospitalized (n = 588; 2.8%). A smaller proportion of individuals who were not hospitalized met the CPG recommendations for mean HbA_{1c} (n = 6,015; 28.7%), as compared to individuals who were hospitalized (n = 5,245; 29.6%) while a greater proportion of individuals who were not hospitalized met the CPG target median UACR levels (n = 9,498; 45.3%), as compared to individuals who were hospitalized (n = 5,024;

Table 4.5

Bivariate Analysis of Hospitalization and Characteristics of Adults with Diabetes in Newfoundland and Labrador (n = 38,697)

Variable	Was not hospitalized n (%)	Was hospitalized n (%)	p-value	Standard difference (95% CI)
TOTAL	**20,987 (100.0)**	**17,710 (100.0)**		
Predisposing factors				
Sex			0.048	0.020 (0.000 – 0.040)
Female	10,419 (49.6)	8,971 (50.7)		
Male	10,568 (50.4)	8,739 (49.3)		
Age (years)			< 0.0001	0.448 (0.427 – 0.468)
20-34	330 (1.6)	220 (1.2)		
35-49	1,928 (9.2)	886 (5.0)		
50-64	7,213 (34.4)	3,864 (21.8)		
65-79	9,029 (43.0)	8,110 (45.8)		
80+	2,487 (11.9)	4,630 (26.1)		
Enabling factors				
Rurality			0.030	0.022 (0.002 – 0.042)
Rural	11,669 (55.6)	10,042 (56.7)		
Urban	9,318 (44.4)	7,668 (43.3)		
Number of FPs per 1,000 pop.			0.151	0.02 (0.0 – 0.04)
0 - <1.0	3,049 (14.5)	2,547 (14.4)		
1.0 - 1.25	7,978 (38.0)	6,902 (39.0)		
>1.25	9,960 (47.5)	8,261 (46.6)		
Physician turnover			< 0.0001	0.067 (0.047 – 0.087)
Low (0 - ≤25)	8,732 (41.6)	7,230 (40.8)		
Moderate (>25 - ≤50)	11,533 (55.0)	9,656 (54.5)		
High (>50 - 100)	588 (2.8)	709 (4.0)		
No FPs in EZ	134 (0.6)	115 (0.6)		
Acute care beds per 1,000 population			0.931	0.007 (-0.013 – 0.027)
0 - 1 beds	1,407 (6.7)	1,201 (6.8)		
> 1 - 2 beds	2,486 (11.8)	2,076 (11.7)		
> 2 - 3 beds	7,182 (34.2)	6,103 (34.5)		
3+	9,912 (47.2)	8,330 (47.0)		
Need factors				
HbA1c mean*			0.039	0.021 (0.001 – 0.041)
Did not meet CPG	14,972 (71.3)	12,465 (70.4)		
Met CPG	6,015 (28.7)	5,245 (29.6)		
LDL-C mean*			0.383	0.009 (-0.011 – 0.029)
Did not meet CPG	13,321 (63.5)	11,165 (63.0)		
Met CPG	7,666 (36.5)	6,545 (37.0)		
UACR median*			< 0.0001	0.356 (0.336 – 0.376)
Did not meet CPG	11,489 (54.7)	12,686 (71.6)		
Met CPG	9,498 (45.3)	5,024 (28.4)		
Process variables				
HbA1c testing frequency			< 0.0001	0.187 (0.167 – 0.207)
Did not meet CPG	17,304 (82.5)	13,757 (77.7)		
Met CPG	3,229 (15.4)	2,957 (16.7)		
Did not receive any tests	454 (2.2)	996 (5.6)		
LDL-C testing frequency			< 0.0001	0.281 (0.261 – 0.301)
Did not meet CPG	12,711 (60.6)	10,491 (59.2)		
Met CPG	7,393 (35.2)	5,197 (29.3)		
Did not receive any tests	883 (4.2)	2,022 (11.4)		
UACR testing frequency			< 0.0001	0.222 (0.202 – 0.242)
Did not meet CPG	13,561 (64.6)	9,713 (54.8)		
Met CPG	1,783 (8.5)	1,429 (8.1)		
Did not receive any tests	5,643 (26.9)	6,568 (37.1)		

CI – confidence interval; FP – family physician; EZ – economic zone; HbA1c – glycated hemoglobin; LDL-C – low-density lipoprotein cholesterol; UACR – urine albumin-to-creatinine ratio; CPG – Clinical Practice Guideline

* - individuals with zero tests are coded as 'did not meet.'

28.4%). There were no significant differences between individuals who were and were not hospitalized on meeting the CPG recommendations for mean LDL-C level (n = 6,545; 37.0% vs. n = 7,666; 36.5%). A smaller proportion of individuals who were not hospitalized, met the CPG for HbA_{1c} testing frequency (n = 3,229; 15.4%) as compared to individuals who were hospitalized (n = 2,957; 16.7%). Conversely, a greater proportion of individuals who were not hospitalized, as compared to individuals who were hospitalized, received the recommended frequency of LDL-C (n = 7,393; 35.2% vs. 5,197; 29.3%) and UACR testing (n = 1,783; 8.5% vs. n = 1,429; 8.1%). Most of the bivariate comparisons were highly significant.

The standardized differences are presented to show the magnitude of the difference. Half of the significant comparisons – sex, rurality, physician turnover, and HbA_{1c} level – had a standardized difference below 0.1, suggesting that the magnitude of the difference is low (e.g., less meaningful). The other half – age, UACR median, HbA_{1c}, LDL-C, and UACR testing frequencies – had standardized differences ranging from 0.187 to 0.448, indicating larger differences between those who were and were not hospitalized.

4.4.1 Multivariable Logistic Regression of Predictors of Hospitalization

Table 4.6 shows the results of the multivariable binomial logistic regression predicting the likelihood of hospitalization while controlling for other covariates. Turnover was associated with hospitalization. Individuals living in an economic zone with high turnover were 1.451 times more likely to be hospitalized than individuals living in an economic zone with low turnover (95% CI 1.289 - 1.632). Additionally, meeting the recommended level for HbA_{1c} and UACR was associated with a lower likelihood of

hospitalization than individuals who did not meet recommended HbA_{1c} or UACR levels (OR = 0.949; 95% CI 0.906 – 0.993, OR = 0.545; 95% CI 0.521 – 0.569, respectively). The interaction between age and sex suggests that males within the three oldest age groups (50-64, 65-79, 80+) had an increased likelihood of being hospitalized (OR = 2.018, 95% CI 1.406 – 2.895; OR = 2.464, 95% CI 1.724 – 3.523; OR = 2.718, 95% CI 1.885 – 3.920, respectively). Females aged 35-49 and 50-64 had a lower likelihood of hospitalization, as compared to females aged 20-34 (OR = 0.573, 95% CI 0.440 – 0.746; OR = 0.537, 95% CI 0.419 – 0.689, respectively). Males aged 20-34 had a lower likelihood of hospitalization than females aged 20-34 (OR = 0.437, 95% CI 0.308 – 0.622).

This model was statistically significant ($\chi^2(14) = 2769.845$, $p < 0.0001$), passed the Hosmer Lemeshow test ($p > 0.05$), and explained 9.2% for the variance in hospitalization (Nagelkerke R^2). Residuals were examined, and no outliers were found.

Table 4.6

Predictors of Hospitalization among Adults with Diabetes in Newfoundland and Labrador (n = 38,697)

	β	Standard error	Wald Chi-square	df	p-value	Odds ratio	Odds ratio 95% CI
Constant	0.342	0.124	7.584	1	0.006	1.408	
Age (years)							
20-34						1.00	
35-49	-0.557	0.135	17.068	1	< 0.0001	0.573	(0.440 – 0.746)
50-64	-0.621	0.127	24.045	1	< 0.0001	0.537	(0.419 – 0.689)
65-79	-0.240	0.125	3.675	1	0.055	0.786	(0.615 – 1.005)
80+	0.362	0.128	8.024	1	0.005	1.436	(1.118 – 1.845)
Sex							
Female						1.00	
Male	-0.827	0.180	21.187	1	< 0.0001	0.437	(0.308 – 0.622)
Age*Sex							
Male*35-49	0.223	0.198	1.270	1	0.260	1.250	(0.848 – 1.844)
Male*50-64	0.702	0.184	14.531	1	< 0.001	2.018	(1.406 – 2.895)
Male*65-79	0.902	0.182	24.472	1	< 0.0001	2.464	(1.724 – 3.523)
Male*80+	1.000	0.187	28.654	1	< 0.0001	2.718	(1.885 – 3.920)
Mean HbA1c value*							
Did not meet CPG						1.00	
Met CPG	-0.053	0.024	5.031	1	0.025	0.949	(0.906 – 0.993)
Median UACR value*							
Did not meet CPG						1.00	
Met CPG	-0.608	0.022	733.171	1	< 0.0001	0.545	(0.521 – 0.569)
Turnover							
Low turnover						1.00	
Moderate turnover	-0.037	0.022	2.819	1	0.093	0.964	(0.923 – 1.006)
High turnover	0.372	0.060	38.171	1	< 0.0001	1.451	(1.289 – 1.632)
No FPs in EZ	0.150	0.132	1.293	1	0.255	1.162	(0.897 – 1.506)

df – degrees of freedom; OR – odds ratio; CI – confidence interval; HbA1c – glycated hemoglobin; CPG – Clinical Practice Guideline; UACR – urine albumin-to-creatinine ratio; FP – family physician; EZ – economic zone

* individuals with zero tests are coded as 'did not meet.'

4.5 Mortality

Table 4.7 shows the characteristics of the individuals based on mortality; individuals who lived (n = 33,485; 86.5% of the study sample) compared to individuals who died (n = 5,212; 13.5% of the study sample). A greater proportion of individuals who lived were female (n = 16,909; 50.5%) and resided in rural census subdivisions (n = 18,874; 56.4%), as compared to individuals who died (n = 2,481; 47.6% and n = 2,837; 54.4%). People who died were older than people who lived, with a greater proportion of individuals in the 80+ years old age group who had died, as compared to individuals who had lived (n = 2,311, 44.3% and n = 4,806, 14.4%, respectively). A greater proportion of individuals who died resided in an economic zone with three or more acute care beds per 1,000 population (n = 2,569; 49.3%), as compared to individuals who lived (n = 15,673; 46.8%). There was no significant difference between people who lived and people who died on the number of FPs per 1,000 population or the level of physician turnover. Additionally, there was no significant difference in the proportion of individuals who lived and individuals who died whose mean HbA_{1c} met the Diabetes Canada CPG target (n = 9,751; 29.1% and n = 1,509; 28.9%, respectively). There was a greater proportion of individuals who lived who had a mean LDL-C (n = 12,623; 37.7%) and a median UACR (n = 13,954; 41.7%) that met CPG target level, as compared to individuals who died (n = 1,588; 30.5% and n = 568; 10.9%, respectively). A smaller proportion of individuals who lived, as compared to individuals who died, met Diabetes Canada CPG testing frequency for HbA_{1c} (n = 5,093; 15.2% vs. n = 1,093; 21.0%) and UACR (n = 2,676; 8.0% vs. n = 536; 10.3%). However, a greater proportion of those who lived, as compared to

Table 4.7

Bivariate Analysis of Mortality and Characteristics of Adults with Diabetes in Newfoundland and Labrador (n = 38,697)

Variable	Lived n (%)	Died n (%)	p-value	Standard difference 95% CI
TOTAL	**33,485 (100.0)**	**5,212 (100.0)**		
Predisposing factors				
Sex			< 0.001	0.058 (0.029 – 0.087)
Female	16,909 (50.5)	2,481 (47.6)		
Male	16,576 (49.5)	2,731 (52.4)		
Age (years)			< 0.0001	0.822 (0.792 – 0.852)
20-34	544 (1.6)	6 (0.1)		
35-49	2,734 (8.2)	80 (1.5)		
50-64	10,409 (31.1)	668 (12.8)		
65-79	14,992 (44.8)	2,147 (41.2)		
80+	4,806 (14.4)	2,311 (44.3)		
Enabling factors				
Rurality			0.009	0.039 (0.10 – 0.068)
Rural	18,874 (56.4)	2,837 (54.4)		
Urban	14,611 (43.6)	2,375 (45.6)		
Number of FPs per 1,000 pop.			0.072	0.034 (0.005 – 0.063)
<1.0	4,865 (14.5)	731 (14.0)		
1.0-1.25	12,930 (38.6)	1,950 (37.4)		
>1.25	15,690 (46.9)	2,531 (48.6)		
Physician turnover			0.143	0.035 (0.006 – 0.064)
Low (0-≤25)	13,752 (41.1)	2,210 (42.4)		
Moderate (>25-≤50)	18,397 (54.9)	2,792 (53.6)		
High (>50-100)	1,114 (3.3)	183 (3.5)		
No FPs in EZ	222 (0.7)	27 (0.5)		
Acute care beds per 1,000 population			0.003	0.056 (0.026 – 0.085)
0 - 1 beds	2,263 (6.8)	345 (6.6)		
> 1 - 2 beds	4,005 (12.0)	557 (10.7)		
> 2 - 3 beds	11,544 (34.5)	1,741 (33.4)		
3+	15,673 (46.8)	2,569 (49.3)		
Need factors				
HbA1c mean*			0.804	0.004 (-0.025 – 0.033)
Did not meet CPG	23,734 (70.9)	3,703 (71.1)		
Met CPG	9,751 (29.1)	1,509 (28.9)		
LDL-C mean*			< 0.0001	0.153 (0.124 – 0.182)
Did not meet CPG	20,862 (62.3)	3,624 (69.5)		
Met CPG	12,623 (37.7)	1,588 (30.5)		
UACR median*			< 0.0001	0.746 (0.717 – 0.776)
Did not meet CPG	19,531 (58.3)	4,644 (89.1)		
Met CPG	13,954 (41.7)	568 (10.9)		
Process variables				
HbA1c testing frequency			< 0.0001	0.693 (0.664 – 0.723)
Did not meet CPG	27,975 (83.5)	3,086 (59.2)		
Met CPG	5,093 (15.2)	1,093 (21.0)		
Did not receive any tests	417 (1.2)	1,033 (19.8)		
LDL-C testing frequency			< 0.0001	0.850 (0.821 – 0.880)
Did not meet CPG	21,217 (63.4)	1,985 (38.1)		
Met CPG	11,093 (33.1)	1,497 (28.7)		
Did not receive any tests	1,175 (3.5)	1,730 (33.2)		
UACR testing frequency			< 0.0001	0.878 (0.848 – 0.908)
Did not meet CPG	21,911 (65.4)	1,363 (26.2)		
Met CPG	2,676 (8.0)	536 (10.3)		
Did not receive any tests	8,898 (26.6)	3,313 (63.6)		

CI – confidence interval; FP – family physician; EZ – economic zone; HbA1c – glycated hemoglobin; LDL-C – low-density lipoprotein cholesterol; UACR – urine albumin-to-creatinine ratio; CPG – Clinical Practice Guideline

* - individuals with zero tests are coded as 'did not meet.'

individuals who died, met Diabetes Canada CPG for LDL-C testing frequency LDL-C (n = 11,093; 33.1% vs. n = 1,497; 28.7%).

Among the comparisons that were found to be significant at $p > 0.05$ level, three had standardized differences below 0.1: sex, rurality, and the number of acute care beds per 1,000 population. The magnitude of difference between individuals who lived and individuals who died for the remaining six significant comparisons ranged from 0.153 for LDL-C mean level meeting the recommended target to 0.822 for age and 0.878 for UACR testing frequency, suggesting a moderate to large magnitude of difference for these comparisons.

4.5.1 Multivariable Logistic Regression of Predictors of Mortality

Table 4.8 shows the results of the multivariable binomial logistic regression predicting the likelihood of death while controlling for other covariates. Turnover was not found to be significantly associated with death. Covariates significantly related to death were age, sex, the number of acute care beds per 1,000 population, and whether the individual met LDL-C and UACR target levels. The interaction between age and sex was tested, but the interaction was not significant. When examining differences between age groups, all age groups older than 20-34 years (35-49, 50-64, 65-79, and 80+ had a higher likelihood of death, with the 80+ age group reporting the highest odds ratio (OR = 35.108; 95% CI 15.638 – 78.826), as compared to individuals aged 20-34 years. Males had a greater likelihood of death than females (OR = 1.264, 95% CI 1.186 – 1.346). Individuals living in an economic zone with three or more acute care beds per 1,000 population were more likely to die than individuals living in an economic zone with 0-1 beds (OR = 1.224; 95% CI 1.077 – 1.392). Individuals meeting targets for LDL-C and

UACR levels were less likely to die than individuals who were not meeting recommended targets (OR = 0.671, 95% CI 0.628 – 0.718 and OR = 0.220, 95% CI 0.201 – 0.241, respectively).

Table 4.8

Predictors of Death among Adults with Diabetes in Newfoundland and Labrador (n = 38,697)

	β	Standard error	Wald Chi-square	df	p-value	Odds ratio	Odds ratio 95% CI
Constant	-4.137	0.416	98.649	1	< 0.0001	0.016	
Sex							
Female						1.00	
Male	0.234	0.032	52.490	1	< 0.0001	1.264	(1.186 – 1.346)
Age (years)							
20-34						1.00	
35-49	0.937	0.427	4.808	1	0.028	2.552	(1.105 – 5.895)
50-64	1.732	0.414	17.534	1	< 0.0001	5.654	(2.513 – 12.720)
65-79	2.495	0.412	36.602	1	< 0.0001	12.126	(5.403 – 27.215)
80+	3.558	0.413	74.364	1	< 0.0001	35.108	(15.638 – 78.826)
Acute care beds per 1,000 pop							
0 - 1 bed						1.00	
> 1 - 2 beds	-0.070	0.078	0.807	1	0.369	0.933	(0.801 – 1.086)
> 2 - 3 beds	0.051	0.067	0.567	1	0.451	1.052	(0.922 – 1.200)
3+	0.202	0.066	9.544	1	0.002	1.224	(1.077 – 1.392)
Mean LDL-C value*							
Did not meet CPG						1.00	
Met CPG	-0.399	0.034	134.810	1	< 0.0001	0.671	(0.628 – 0.718)
Median UACR value*							
Did not meet CPG						1.00	
Met CPG	-1.514	0.047	1045.865	1	< 0.0001	0.220	(0.201 – 0.241)

df – degrees of freedom; OR – odds ratio; CI – confidence interval; LDL-C – low-density lipoprotein cholesterol;
CPG – Clinical Practice Guideline; UACR – urine albumin-to-creatinine ratio
* individuals with zero tests are coded as 'did not meet.'

This model was statistically significant ($\chi^2(13) = 4482.023$, $p < 0.0001$), passed the Hosmer Lemeshow test ($p > 0.05$), and explained 20.0% of the variance in mortality (Nagelkerke R^2). Residuals were examined, and 1,345 (3.5%) cases had a standard

deviation greater than two. Cook's distance was calculated, and none of the cases had a value greater than one; therefore, all were retained.

Chapter 5: Discussion

5.1 Overview of Findings

This study examined the factors related to glycemic control, hospitalization, and mortality among adults with diabetes in NL. I hypothesized that family physician (FP) turnover would be related to an increased likelihood of poor glycemic control, hospitalization, and mortality. The findings of this study provided mixed support for the hypotheses. Results showed that FP turnover was associated with glycemic control and hospitalization but not mortality. The direction of the relationship between FP turnover and hospitalization was as expected, as high FP turnover was associated with increased risk of hospitalization, but the direction of the relationship between FP turnover and glycemic control was not as expected (i.e., individuals living in economic zones with moderate turnover had decreased likelihood of meeting glycemic control targets; individuals living in economic zones with no FPs had increased likelihood of meeting glycemic control targets).

5.1.1 Glycemic Control

Overall, 70.9% of the sample did not meet the recommended HbA_{1c} level. Previous Canadian studies have shown that around 50-60% of individuals have good glycemic control over a one-year period (Coons et al., 2017; Green et al., 2020; Lukewich et al., 2020). This present study examined glycemic control over five years, and, because the time since diagnosis is associated with poorer glycemic control (Al-Lawati et al., 2012; Benoit et al., 2005; Chiu & Wray, 2010; Martono et al., 2016), it is unsurprising that rates of good glycemic control over five years are worse than single-year studies. When controlling for other covariates, individuals living in moderate turnover economic

zones were less likely to meet the recommended HbA_{1c} target. In contrast, individuals living in economic zones with no FPs were more likely to meet the recommended target than individuals living in economic zones with low FP turnover.

Table 5.1 shows a summary of study results. This study's findings provided mixed support for the hypothesis that FP turnover is associated with glycemic control. FP turnover was significantly associated with glycemic control but not in the expected direction. The results showed that people living in economic zones with moderate FP turnover were less likely to have achieved an HbA_{1c} level of 7.0% or lower than individuals living in economic zones with low FP turnover. However, individuals residing in economic zones with no FPs had an increased likelihood of meeting the recommended HbA_{1c} target level, as compared to individuals residing in economic zones with low FP turnover. Additional analyses of process of care outcomes (Appendix H) had also shown that individuals living in regions with no FPs received more frequent HbA_{1c} testing than individuals living in regions with low FP turnover. These findings suggest that individuals living in regions with no FPs are more likely to receive care congruent with the Diabetes Canada CPG.

Table 5.1

Summary of Results

	Low Turnover in EZ	Moderate Turnover in EZ	High Turnover in EZ	No Family Physicians in EZ
Outcomes				
Glycemic Control	Reference group	**Poorer**	NS	**Better**
Hospitalization	Reference group	NS	**Poorer**	NS
Death	Reference group	NS	NS	NS
Process of Care (met guidelines [yes/no])				
HbA1c	Reference group	**Better**	**Better**	**Better**
LDL-C	Reference group	**Poorer**	**Poorer**	**Better**
UACR	Reference group	NS	**Poorer**	**Better**

EZ – economic zone; NS – not significant; LDL-C low-density lipoprotein cholesterol; UACR – urine albumin-to-creatinine ratio

Individuals living in economic zones with high FP turnover had the same likelihood of meeting recommended HbA_{1c} target levels as those who lived in zones with low FP turnover. The magnitude of the odds ratio of the high FP turnover group (OR = 1.137; 95 CI 0.995 - 1.298) was close to significance, indicating that people living in regions with high FP turnover were more likely to have better glycemic control. This association may have reached significance if examined using a larger sample size. The results are consistent with the mixed results of other studies examining the relationship between continuity of care and glycemic control. While some studies have found no association between continuity of care and glycemic control (Gulliford et al., 2007), others have found that better continuity is associated with better glycemic control (Lustman et al., 2016; Maciejewski et al., 2017; Mainous et al., 2004). Interestingly, one

study found no additional benefits resulting from having a usual provider of care compared to having a usual *place* of care (Mainous et al., 2004). The findings from this study suggest that, for glycemic control, it is more important to have a place to receive primary care than a consistent provider.

In NL, primary care is typically provided by FPs, with limited support from other providers, such as nurses, and limited implementation of interdisciplinary team-based care (Mathews et al., 2020). Instead, primary care is most often delivered by FPs working in solo practices or team-based practices with other FPs. Given that NL relies on FPs for primary care delivery and has limited integration of other providers, it is likely that both place and provider of care are disrupted with FP turnover. It may be that the turnover of FPs in regions that are reliant on FPs for primary care would disrupt all three types of continuity of care identified by Haggerty and colleagues (2003); relational, management, and informational. Having a regular place of care, particularly a patient-centred medical home (The College of Family Physicians of Canada, 2019), staffed by an interdisciplinary, collaborative team, would allow the maintenance of management and informational continuity, even if relational continuity is disrupted. NL has three patient-centered medical homes, all within St. John's but has plans to develop additional clinics in other regions of the province. Policymakers within the NL government and Regional Health Authorities need to introduce these models more widely across the province to improve the integration of other primary care providers and potentially lessen the impact of FP turnover on patients in the province.

Future research could closely examine jurisdictions with team-based primary care to examine the effect of FP turnover when there are other primary care providers

available (e.g., RNs, NPs). Additionally, further research could be conducted in NL to compare regions with a high level of FP turnover (e.g., moderate-high turnover) to regions with consistent primary care availability (e.g., regions with low FP turnover or regions with no FPs). These proposed studies would provide an indication of the effectiveness of multidisciplinary teams for primary care delivery and the effect of consistent availability to primary care services in the province.

There was a high correlation between FP turnover, rurality, and the number of acute care beds and the number of FPs per 1,000 population; thus, only the number of acute care beds and FP turnover were included in the analyses. The high correlation among the variables indicates similarities between regions based on turnover, rurality, and availability of acute care beds and FPs. These high correlations are relatively unsurprising. Rural regions of the province experience a higher rate of physician turnover and have fewer health care facilities, such as hospitals (Knight et al., 2017; Twells et al., 2005). Regardless, this study's outcomes found that regions in the province with no FPs had similar or better outcomes than economic zones with low FP turnover. Regions with no FPs were more likely to receive the CPG recommended testing frequency for HbA_{1c}, LDL-C, and UACR than regions with low FP turnover, suggesting that patient management in these regions is better. However, this current study does not have data to indicate who is providing care for these individuals. In this study, there were only two economic zones with no FPs, and both are in Labrador. Health care in these communities is provided by Community Health Clinics staffed by registered nurses, nurse practitioners, and visiting FPs (Labrador-Grenfell Health, 2020a, 2020b). Further research is needed to understand the effectiveness of this model of care delivery.

Several factors may moderate the relationship between health care services, such as access to primary care and glycemic control. American studies have established that patients with diabetes who do not have insurance are at risk of poorer glycemic control than insured patients (Benoit et al., 2005; Chew et al., 2008). This suggests that worse access to necessary health care, including primary care appointments, medications, and diabetic supplies, may predict poor glycemic control. Canadian studies offer additional insight into these findings; in Canada, physician visits are publicly insured, but medication and diabetes supplies may not be. Attributed to the lack of public insurance for medications and diabetic supplies, Canadian studies have found that individuals with no drug insurance may have difficulty paying for diabetes supplies, which contributes to higher HbA_{1c} levels (Bowker et al., 2004; McBrien et al., 2017). In fact, the study from McBrien and colleagues (2017) found that individuals who experienced financial barriers, including a lack of drug insurance, had higher HbA_{1c} despite reporting good access to their health care team. Socioeconomic factors may be stronger predictors of glycemic control than health care access alone, but the impact of these factors could not be explored in this current study due to limitations in data availability.

5.1.2 Hospitalization

Within this study, almost half (45.8%) of the population of adults with diabetes were hospitalized at least once, for any reason, between 2011 and 2015. Although it is difficult to make a direct comparison, this study's hospitalization rate is similar to hospitalization rates reported in other studies. Many studies that examined a single year of data found hospitalization rates among people with diabetes to be around 20-25% (Begum et al., 2011; Fu et al., 2014; Li et al., 2015). One Canadian study that included two years

of data found the hospitalization rate among patients with type 2 diabetes to be 24.0% (Ng et al., 2010), while another study examining ten years of data found the hospitalization rate to be 73.4% (Roche & Wang, 2013). A British study, with a follow-up of, on average, 4.8 years, showed a hospitalization rate of 41.4% (hospitalization with a length of stay ≥ one day) (Khalid et al., 2014), similar to the hospitalization rate of 45.8% found in this study. One of the strongest predictors of hospitalization is having a previous hospitalization, which helps explain the plateauing rate of hospitalization as the study period's length increases (Khalid et al., 2014; Ng et al., 2010).

The regression analysis supported the hypothesis – there was a significant association between FP turnover and hospitalization. Further, the results support the direction of the hypothesis – individuals living in economic zones with high FP turnover were 1.45 times more likely to be hospitalized than individuals residing in economic zones with low FP turnover. These results are consistent with the results of a previous study conducted in NL that found low physician retention was related to a higher hospitalization rate (Knight et al., 2017). The findings may also support the use of turnover as a proxy measure of continuity of care, given that continuity of care is consistently associated with hospitalization (Gruneir, Bronskill, et al., 2016; Petrosyan et al., 2020; Worrall & Knight, 2011).

5.1.3 Mortality

Results show that 5,212 (13.5%) of the study sample died, from any cause, between 2011 and 2015. The mortality rate of individuals with diabetes in this study was more than double that of NL's general population; over the same period, NL's general population experienced approximately 23,830 (5.7%) deaths among individuals over the

age of 20 years (Community Accounts, 2020). The mortality rate of individuals in this study is similar to that of other studies, which have reported the mortality rate of individuals with diabetes to be around 2.7% annually (Gregg et al., 2012; Lipscombe et al., 2010), which, if extrapolated over five years, would be the same as the 13.5% reported in this thesis.

The analyses did not support the hypotheses. There was no relationship between FP turnover and mortality. A person's cause of death was not available within the Chronic Disease Registry. I hypothesized that physician turnover would interrupt continuity of care, which would result in poorer diabetes outcomes and a greater number of deaths. Likely, continuity of care would only affect deaths that could be avoided or delayed through disease management and prevention; therefore, examining specific causes of death might clarify the relationship between physician turnover and mortality. However, previous research has shown that it is challenging to identify deaths related to diabetes due to issues with reporting diabetes among the causes of death and the large number of complications that may result from diabetes (Lu et al., 2010), creating a challenge when examining the relationship between diabetes and mortality.

5.2 Andersen and Newman's Behavioural Model of Health Services Utilization

Andersen and Newman's Behavioural Model for Health Services Utilization has been applied across many studies that have examined factors related to health care use. Studies applying this framework have typically argued that need factors are the strongest predictors of health services utilization, followed by predisposing, and finally enabling (Andersen, 1995; Salam-White et al., 2014). One older systematic review examined the role of predisposing, enabling, and need factors on hospitalization and found that most

studies found no relationship between predisposing and enabling factors and hospitalization, but need factors were significant predictors of hospitalization (De Boer et al., 1997). However, a more recent systematic review has suggested that it may not be possible to determine which factor is the strongest predictor of health services use, given the heterogeneity of studies applying the model (Babitsch et al., 2012). Heterogeneity between studies seems to primarily result from the different types of health services examined (e.g., primary care, mental health services, hospitalization) and the inclusion and operationalization of the included covariates. Many studies that have used Andersen and Newman's model extract their data from secondary and administrative datasets; thus, they must work with the data and variables that are readily available. In addition, the heterogeneity between various studies may be influenced by the researchers' choice of whether a variable should be a predisposing, enabling, or need factor. As discussed in Babitsch et al. (2012), factors such as sex and age are often considered to be predisposing factors. Still, they may act as need factors, as both sex and age are associated with morbidity and mortality. Within the study, age and sex were significant predictors of all three outcomes, and the interaction between age and sex was a predictor of glycemic control and hospitalization. Need factors, such as LDL-C and UACR levels, were not consistently found to be significant predictors, but when they were significant, they were among the strongest (i.e., had the largest odds ratio). The strong relationship between UACR levels and hospitalization and LDL-C and UACR levels with mortality may suggest the presence of comorbid conditions, such as cardiovascular or kidney disease. Future studies that can characterize the presence of multimorbidity would be required to explore this relationship further.

5.2.1 Predisposing Factors

Regarding predisposing factors, the results of this study showed that age and sex were related to all three outcomes – glycemic control, hospitalization, and mortality. There was also a significant association between glycemic control and hospitalization and the age and sex interaction term.

This current study found that older age is a predictor of better glycemic control, consistent with other works (Al-Lawati et al., 2012; Benoit et al., 2005; Chiu & Wray, 2010; Martono et al., 2016). The relationship between age and glycemic control may be due to exceptionally poor glycemic control among younger individuals instead of better control among older individuals. This is supported by the fact that several studies (Al-Lawati et al., 2012; Benoit et al., 2005; Chiu & Wray, 2010; Martono et al., 2016) have established that longer duration of diabetes is a predictor of *poorer* glycemic control, suggesting that diagnosis of diabetes at a younger age is predictive of poorer glycemic control across the lifespan. Unfortunately, due to data limitations in Newfoundland and Labrador (NL), duration of diabetes could not be included as a variable in these analyses. Although the case date is included within the Chronic Disease Registry, this variable has two major weaknesses. Firstly, the database only looks back to 1995; therefore, there are no cases in the Registry with a diagnosis before this date. Secondly, laboratory data were only included in the Chronic Disease Registry as of 2009. When laboratory data were added to the database in 2009, the diabetes incidence appears to be more than two times higher in 2009 than in previous years, as previously unidentified cases are added to the database. Given these limitations, the relationship between time since diagnosis and glycemic control cannot be ascertained using these data. The interaction between age and

sex was a significant predictor of glycemic control. Generally, older people were more likely to meet recommended glycemic control targets, although older females (65-79, 80+) were more likely to meet glycemic control targets than older males. Previous studies that have employed Andersen and Newman's framework have typically found age and sex to be predictive of health services utilization, but the direction of the association may vary depending on the type of health services being examined and other variables included in the study (e.g., older people have been found to be less likely to use addiction and mental health services [Babitsch et al., 2012]). Sex is often found to be related to health services utilization and is often found to predict primary care utilization. Females more frequently visit their primary care provider, especially when comparing younger females to younger males (Babitsch et al., 2012). The higher utilization of primary care by females may have contributed to the sex differences in glycemic control. Complete billing data would be required to determine whether a sex difference in primary care utilization existed within the sample.

In this study, young males (aged 20-34) and females aged 35-49 and 50-64 were less likely to be hospitalized, while individuals aged 80+ years of both sexes were more likely to be hospitalized than females aged 20-34-years. Age had a J-shaped relationship with hospitalization -- individuals aged 35-49 and 50-64 were less likely to have been hospitalized than individuals aged 20-34, while individuals aged 80+ were more likely to be hospitalized. When examining age as a continuous variable, increasing age is typically related to an increased risk of hospitalization (Khalid et al., 2014). Patterns of hospitalization can vary depending on age grouping choices. One Canadian study found no difference in hospitalization rates between 12 to 44-year-olds and 45-64 years with

diabetes (Ng et al., 2010), similar to this present study. Studies that have examined diabetes among younger individuals have found that type 2 diabetes cases among individuals aged 30 years or younger are associated with a higher rate of mortality and complications, particularly cardiovascular complications (Constantino et al., 2013; Lascar et al., 2018). Another study found that high hospitalization rates among individuals under 30 years old were often due to mental illness (Ke et al., 2019). This evidence suggests that early-onset cases of diabetes may be related to comorbid conditions that result in hospitalization, particularly hospitalization for cardiovascular or mental illness. Unfortunately, within this study, the presence of other chronic conditions (i.e., multimorbidity) could not be controlled; therefore, I cannot determine whether the presence of other chronic conditions mediated the relationship between age and hospitalization. Males were less likely to be hospitalized than females and there was a significant interaction between age and sex on the outcome of hospitalization. This is consistent with previous studies that have found sex differences in hospitalization rates, but that this difference is typically influenced by age (Al-Salameh et al., 2020; Moss et al., 1999).

Age was found to be related to mortality rate. All age groups older than 20-34 years had an increased likelihood of death. The findings from this present study are consistent with previous research in this area; older people with diabetes have a higher mortality rate than younger people with diabetes (Lipscombe et al., 2010; Lipscombe & Hux, 2007; Tancredi et al., 2015).

A limited number of predisposing variables were available for use within this study, but it is important to recognize that other variables are associated with health

services use. Predisposing factors, including marital status, education, and ethnicity, can influence health services utilization. Individuals who are married are more likely to access health services, as are those with higher levels of education (Babitsch et al., 2012). Recent immigrants and racial minorities have also been found to access fewer health services (Babitsch et al., 2012). Again, the inclusion of these factors may have helped strengthen the model's explanatory power, and it would be useful if these data were more readily available within chronic disease registries.

5.2.2 Enabling Factors

Among the enabling variables included in the analysis, the number of acute care beds per 1,000 population was associated with glycemic control and mortality, while FP turnover was associated with glycemic control and hospitalization. Individuals living in an economic zone with more than one acute care bed per 1,000 population had an increased likelihood of meeting HbA_{1c} target levels. It may be that having less than one acute care bed per capita may indicate a lack of other resources, including limited access to allied health professionals, poor food environment, and limited access to physical activity opportunities. Travel is also a burden to patients, and regions without hospitals in NL are rural and remote. Distance to health care facilities has been shown to be associated with poorer health outcomes for patients, including glycemic control (Kelly et al., 2016; Zgibor et al., 2011). A more in-depth analysis of the built environment in rural NL would be required to determine the relationship between the built environment and glycemic control in the province.

Results of this study suggest that living in an economic zone with more than three acute care beds per 1,000 population was associated with an increased likelihood of

death, as compared to individuals living in an economic zone with 0-1 acute care beds. It may be that sicker individuals choose to live in areas with better access to care, in the case of this study, access to a hospital. A sensitivity analysis was performed to compare individuals who did and did not move economic zones during the study period to determine whether individuals who moved during the study period were sicker than those who did not move (Appendix E). This analysis did not provide support for this explanation, as it showed that a smaller proportion of individuals who moved died between 2011 and 2015, as compared to individuals who did not move. However, if individuals moved before the study period (i.e., 2011), this would not have been captured by the study. Data from a longer period would be required to explore this further.

Enabling variables were measured at the geographic level of economic zone. Individuals were assigned values for these variables, such as level of FP turnover and number of acute care beds per 1,000 population, based on their economic zone of residence. The assignment of variables based on geography as opposed to individual characteristics may result in an ecological fallacy. An ecological fallacy occurs when conclusions are drawn for an individual based on their group characteristics, in this case, characteristics of their economic zone (Dohoo et al., 2010). For example, individuals may not experience the level of turnover assigned to their economic zone (i.e., some individuals living in economic zones with high FP turnover may experience a level of turnover higher or lower than average). Given this, I have been careful not to make attributions to individuals residing in these regions and framed the results based on the aggregate of the economic zone. The precision of the analysis would have been improved

if turnover could be calculated for each patient. Unfortunately, this is impossible for all patients in NL, as billing data are not available for all patients in the province.

5.2.3 Need Variables

The need variables included in the analyses indicated individuals met target levels for HbA_{1c}, LDL-C, and UACR. This study found that HbA_{1c} level was related to hospitalization, LDL-C was associated with mortality, and UACR level was related to glycemic control, hospitalization, and death. Individuals meeting HbA_{1c} targets were slightly less likely to have been hospitalized, while people who were off-target for LDL-C were more likely to have died. UACR levels were associated with all three outcomes of interest. Individuals who were on target for UACR were more likely to meet HbA1c target levels and less likely to have been hospitalized and died.

Previous research has shown that HbA_{1c} and UACR levels are predictive of hospitalization (Khalid et al., 2014; Yu & Simmons, 2013). Research has established that higher HbA_{1c} and UACR levels are predictive of complications; therefore, it is unsurprising that these covariates were found to be related to hospitalization (Berard et al., 2018; McFarlane et al., 2018). Similarly, studies have also shown that higher cholesterol and UACR are predictive of higher mortality; therefore, findings of this current study are consistent with previous studies (Araki et al., 2012; Drury et al., 2011; Mancini et al., 2018; Tancredi et al., 2015).

Appendix H shows the results of the regression analyses examining predictors of HbA_{1c}, LDL-C, and UACR testing frequencies. These variables were also tested as predictors of the outcomes of glycemic control, hospitalization, and mortality but these variables were not included in the final model. Data are not available on who ordered the

tests or where the tests were ordered (e.g., ordered by FP in community, long-term care setting, or in hospital). When considering the Clinical Practice Guidelines, individuals should have at least two HbA_{1c} tests and one LDL-C and UACR test annually (Imran et al., 2018; Mancini et al., 2018; McFarlane et al., 2018). In the initial analysis plan, the testing frequency was included as both a covariate and an outcome. I hypothesized that individuals who were not meeting target levels would have more frequent testing to monitor their levels closely; therefore, it was expected that individuals with more tests would have higher test values. This was not consistently shown, and it could not be determined whether individuals received fewer tests because they maintained lower levels or whether their primary care provider poorly managed them. Similarly, individuals may have been receiving an appropriate number of tests because they had high values or because they were receiving proper management from their primary care provider. Tests may have also been performed during hospitalization and would not be attributable to the behaviours of the FP. Additionally, the database does not identify individuals who reside in long-term care facilities; therefore, I could not control for this within the analyses. Future studies could examine whether dates of testing overlapped with dates of hospitalization or whether patients reside in long-term care facilities to control for testing that occurs outside of a primary care setting.

5.2.3.1 Comorbidities. The presence of comorbid conditions are not included in the analysis. The Charlson comorbidity index is the most extensively studied and commonly applied method of quantifying the presence of comorbidities (S. R. Austin et al., 2015; De Groot et al., 2003; Yurkovich et al., 2015). The Charlson index uses administrative data, specifically ICD codes from hospitalization and physician billing

data, to identify and categorize the presence of comorbidities (Charlson et al., 1994). Comorbidities are weighted based on severity, and the individual is assigned an index score from one to six, with six indicating the presence of multiple or more severe comorbidities. Although this is a validated method of quantifying comorbidities, it was not feasible to use this index for this project. As previously mentioned, 35-40% of physicians in NL do not submit billing data; therefore, billing data cannot identify the presence of comorbid conditions within the group of patients who see these physicians. Although hospitalization data could be used to identify comorbidities, this could only be done for individuals who were hospitalized during the study period. Because hospitalization was examined as an outcome, the analysis would be biased if the Charlson comorbidity index was calculated only for only the portion of the sample who were hospitalized. Implementing shadow-billing[7] for non-FFS physicians would help researchers to complete more thorough research using administrative data.

Another common way to identify comorbidities is through the Canadian Community Health Survey (CCHS). The CCHS is conducted annually and samples 65,000 Canadians, for a sample of 130,000 people for each two-year cycle (Statistics Canada, 2020a). This survey aims to create a representative sample of Canadians at the level of health region. NL has four health regions, with most individuals residing in the Eastern Health region. For the CCHS, around 4,000 people in NL are surveyed (Statistics Canada, 2013). Given the sample size, analyses at smaller levels of geography are not

[7] Physicians remunerated under alternative payment plans may be required to submit invoices, or shadow bill, for services provided. Physicians may receive minimal or no remuneration for this, but it creates a more complete administrative database (Canadian Institute for Health Information, 2015).

possible; therefore, these data could not be used in this current study. Studies conducted in other Canadian provinces, such as those conducted in Ontario, have used physician, hospitalization, and prescription data to describe comorbidities and multimorbidity (Gruneir, Markle-Reid, et al., 2016; Slater et al., 2019). NL does not have complete physician billing or prescription databases.

5.3 Strengths

Although this study provided mixed support for the hypotheses, there were several strengths in the methodology. The data sources used in the analyses include all individuals covered by the provincial Medical Care Plan (MCP). The Chronic Disease Registry is a complete registry of people with diabetes in the province. It uses two case definitions to identify individuals in the population with diabetes (CCDSS and laboratory case definition) and, by using laboratory data, includes a larger population than the CCDSS database alone. Provincial hospitalization and laboratory databases containing all hospitalizations, HbA_{1c}, LDL-C, and UACR tests for individuals with diabetes were used in this study. The Physician and Medical Practice Database provides information on all physicians who practice in the NL, including practice locations. These secondary, population-based data sources allowed for an objective analysis of the population of people with diabetes in NL. This study used FP turnover as a proxy measure of continuity of care. This novel measure is important in NL because complete billing data are unavailable for 35-40% of physicians, making it impossible to calculate frequently used measures of continuity of care (e.g., usual provider continuity, continuity of care index). By using turnover as a proxy, it is possible to calculate a measure of continuity of care inclusive of all people with diabetes in the province. Andersen and Newman's Behavioral

Model of Health Services Utilization has been consistently applied throughout this thesis, including developing the research question, data analysis and interpretation. The use of a theoretical model provides a mechanism for explaining the relationship between predictor variables and the outcomes of interest and allows the results of this study to be compared to similar studies applying this framework.

5.4 Limitations

There were some limitations in the study. Many variables were calculated at the geographic level of economic zone. This design limits the inferences that can be made about individuals. Inferences made at the individual level may result in an ecological inference fallacy. Regardless of this limitation, results showed an association between turnover, as measured at the level of economic zone, and some of the outcomes of interest, such as hospitalization. There was a relatively low number of individuals within the "no FPs in economic zone" group. This study is observational, and the sample was derived from the entire population of individuals with diabetes in NL, after exclusion criteria were applied, therefore, the number of individuals within this group cannot be increased. There were relatively few covariates included within the analyses, thus, the sample size was appropriately powered to determine differences between groups. Additionally, the magnitude of difference between the "no FP" group and the low turnover group suggests that there was a meaningful difference between these groups. Given that regions with no FPs had outcomes similar to or better than regions with low FP turnover, further research is warranted. There are limited secondary data available in NL answer questions regarding the delivery of primary care in these regions, therefore, alternative methods are required. Patient and provider surveys would provide an

understanding of the services delivered and received within these regions. Mixed methods research, including patient and provider interviews, would provide an understanding of the experience with primary care in regions with no FPs. These future potential studies would offer a clearer picture of primary care delivery in regions with no FPs and allow for replication of these models of care in other rural and remote regions in NL.

A cross-sectional design limits the inferences that can be made from the results. The independent and dependent variables were measured over the same period (2011/12-2015/16); therefore, temporal causality cannot be determined. However, based on previous research, it is plausible to assume that increased physician turnover leads to increases in hospitalization instead of hospitalization causing FP turnover. Future studies could perform more advanced analysis, such as a longitudinal analysis, which would provide insight into the temporal relationship between FP turnover and outcomes, such as glycemic control, hospitalization, and mortality. If FP turnover is predictive of health outcomes, such as hospitalization and mortality, it is likely that by measuring the predictor before the outcome the strength of the relationship between the predictor and outcome would be stronger. Additional analysis would be required to understand the temporal relationship between FP turnover and the outcomes of interest, in order to determine the relevant span of time between the predictor and outcome (e.g., does turnover that occurs in one year predict hospitalization in the next?). Although the Chronic Disease Registry includes the entire population of people with diabetes in NL, it has some limitations. The Registry identifies all individuals in the province with type 1 or type 2 diabetes, but it cannot differentiate between the two types due to the case

definitions used. Additionally, the Registry is relatively new, and, to the best of my knowledge, it has not been tested for validity or completeness.

There were limited socioeconomic data available for individuals within the Chronic Disease Registry, which may have contributed to the low explanatory power of the regression models. Socioeconomic variables, such as income and education, have been shown to affect people with chronic diseases such as diabetes. Therefore, effort should be made to include this information within chronic disease databases. Additionally, risk factors for diabetes, such as diet, food security, smoking status, and physical activity levels, can affect health outcomes among people with diabetes (Slater et al., 2019). The inclusion of these variables may have increased the models' explanatory power. In addition to the limited socioeconomic variables, there were limitations in the available data from other secondary sources. For example, studies have shown that comorbidities are predictors of hospitalization and death. Unfortunately, it is not possible to calculate a measure of comorbidities for all patients in NL using available data. Because of a lack of billing data, other comorbidity measures, such as the Charlson Comorbidity Index, cannot be calculated. Similarly, other important process variables, such as eye or foot examinations, could not be assessed. There was potential to include other health data sources, such as the Canadian Community Health Survey, but this survey samples a small percentage of the province, resulting in high variability or missing data for some economic zones. Overall, there is a need for better secondary data availability in NL. Policymakers should encourage the use of shadow billing among APP physicians in the province to improve the completeness of the administrative databases in the province. Additionally, policymakers should consider the implementation and

maintenance of a provincial pharmaceutical database. With the addition of shadow billing and a pharmaceutical database, health services researchers could provide a more accurate depiction of the state of chronic disease in NL. These changes would allow for the calculation of the presence of comorbid conditions, measures of continuity of care, and would provide validated methods of identifying the presence of chronic conditions (e.g., use of pharmaceutical database, physician billing records). The quality of health services research using secondary data could be improved, thereby improving the quality of research evidence produced within the province.

Generalized targets for the testing level variables were used (e.g., a target value of 7.0% for HbA_{1c}). Although the Diabetes Canada Clinical Practice Guidelines recommend this target for most patients, the guidelines recognize that this target may not be appropriate for all individuals (Imran et al., 2018). The guideline indicates that target levels may be as high as 8.5% for patients with limited life expectancy, frailty, who are functionally dependent, or who have recurrent severe hypoglycemia. Using secondary data in its current form, it cannot be ascertained whether patients are achieving their individual target values. Regardless, evidence has established that HbA_{1c} values greater than 7.0% put an individual at risk of complications and is the target for most patients; therefore, it was an appropriate choice for this study.

Individuals who did not receive a specific laboratory test over the study period were classified as having off-target levels for that test type. This method may have resulted in individuals with low levels of HbA_{1c}, LDL-C, or UACR who have not been tested being coded as "off-target." An analysis of the sequelae of high HbA_{1c}, LDL-C, or UACR levels (e.g., presence of comorbid conditions, hospitalizations due to

cardiovascular or renal events) may help clarify whether this coding has appropriately classified individuals as on- or off-target.

5.5 Recommendations

The relationship between turnover and outcomes was not consistently clear, but there are several recommendations to be made from this project. The rate of FP turnover in NL is among the highest in the country and the province will need to develop novel means of providing primary care to the population. Based on the findings of this thesis, I offer two suggestions. First, regions of the province with no family doctors performed similarly to regions with low turnover on the outcomes of glycemic control and hospitalization. In addition, findings within Appendix H suggest that regions with no FPs performed similarly or better than regions with low turnover on the process of care outcome (i.e., frequency of testing). Although the sample size is relatively small, this evidence warrants further investigation. Primary care in these regions is delivered by nurses (Registered Nurses, Nurse Practitioners), telemedicine, and visiting FPs. Given the success of these regions in delivering primary care, it is worth exploring whether there is potential to apply this model of care in other rural and remote regions of the province. Rural regions are more likely to experience high FP turnover and there is a need to develop strategies to encourage the retention of FPs in these regions. Additionally, the results of this study suggest that interdisciplinary care, such as the model of care in regions with no FPs, could be applied within rural regions with high FP turnover to improve outcomes for patients with chronic conditions. Secondly, the primary predictor of interest for this study was turnover of FPs. High rates of physician turnover may indicate a high rate of change in primary care availability, if the region is reliant on FPs

for primary care delivery. Regions with low FP turnover and no FPs may experience more consistent availability of primary care services than regions with high FP turnover. Future studies should examine whether consistent primary care availability leads to better health outcomes among patients, as compared to regions with high rates of change in primary care availability.

Chapter 6: Conclusion

Diabetes is the fifth most prevalent chronic disease in Canada, affecting approximately 3.8 million Canadians, including 68,000 Newfoundland and Labradorians (Diabetes Canada, 2020a, 2020b; Public Health Agency of Canada, 2019b). People with chronic conditions are the highest users of primary care and rely on primary care for disease management (Canadian Institute for Health Information, 2014a; Maddocks et al., 2020; Terner et al., 2011). Although diabetes can be managed through medication, lifestyle, and self-management in collaboration with a primary care provider, it can result in complications that are associated with hospitalization and death (Clement et al., 2018; Diabetes Canada, 2020a). Continuity of care is central to good primary care provision (Baker et al., 2020; Reid et al., 2002). The turnover of family physicians (FPs) threatens continuity of care and may affect primary care delivery. Because of the importance of primary care to chronic disease management, it is essential to understand factors that may be affecting continuity of care and negatively impacting patients in NL.

The thesis applied Andersen and Newman's Behavioural Model of Health Services Utilization to examine whether FP turnover was associated with glycemic control, hospitalization, and mortality among patients with diabetes in Newfoundland and Labrador (NL). The results of this study provided mixed support for the hypotheses; FP turnover was found to be associated with glycemic control and hospitalization but not mortality. Individuals living in economic zones with higher levels of FP turnover had an increased likelihood of hospitalization. Conversely, the direction of the relationship between FP turnover and glycemic control was unclear. The inclusion of predisposing, enabling, and need variables within the analyses revealed other significant contributors to

the outcomes, including age, sex, the number of acute care beds per 1,000 population within the economic zone, and glycated hemoglobin (HbA_{1c}) level.

The analyses did not confirm all the hypotheses developed a priori; however, the results further our understanding of the role of FP turnover in health services research. Previous studies have established the relationship between continuity of care and health outcomes for patients with chronic conditions (Baker et al., 2020; Cho et al., 2015; Knight et al., 2009). This study provided a novel contribution to the field of research on continuity in primary care by examining FP turnover as a proxy measure of continuity of care. As previously established, places such as NL cannot examine the relationship between continuity of care and patient outcomes due to the lack of physician billing data. The results suggest that there is potential for physician turnover to be used as a proxy measure of continuity of care. This study also contributed to chronic disease management research by identifying predisposing, enabling, and need factors that impact glycemic control, hospitalization, and mortality among patients with diabetes.

A strength of this study was the use of provincially representative data, including the Chronic Disease Registry and the Physician and Medical Practice Database. These databases are inclusive of all patients with diabetes in NL and all FPs practicing within the province. Additionally, the use of the Chronic Disease Registry and the Physician and Medical Practice Database makes this project one of the most complete analyses of patients with diabetes performed in NL. Andersen and Newman's Behavioural Model of Health Services Utilization improves the interpretability of the results and allows for a comparison of these studies to others within the field.

This study was limited by the quality of available data and the availability of important variables within the databases. Several important variables, such as disease duration, could not be determined using the existing database. Other variables, such as socioeconomic status, were not available within the databases. These variables (e.g., income, education) are known to affect the prevalence of diabetes and health outcomes for patients with diabetes (Dinca-Panaitescu et al., 2012; Houle et al., 2015). Provincial data custodians could attempt to link additional datasets to the Chronic Disease Registry to better understand the health of the population within the province. The unavailability of physician billing data made it necessary to calculate FP turnover at the level of economic zone. The use of economic zone level data creates the potential for ecological fallacy since a resident in a high turnover zone may enjoy good continuity of care with a provider who has not left the community.

This study provides direction for future studies. For one, this study could be performed in other Canadian provinces where shadow billing data are available to examine the effect of physician turnover at the individual patient level. The availability of physician data allows for the attachment of individual patients to individual physicians, which would allow for a direct comparison between FP turnover and commonly applied measures of continuity of care (e.g., UPC, COC). This comparison would further solidify the use of physician turnover as a measure of continuity of care. Research could also examine whether there is a difference in outcomes between regions with relatively consistent primary care access and regions with high rates of change or turnover. The findings of this study suggest that regions with no FPs often performed similarly or better than regions with low physician turnover. Although the consistency of primary care

access within this current study could not be determined, it is plausible that regions with no FPs can maintain consistent primary care access through nurses and visiting FPs and without the presence of a permanent FP. Future studies should describe the availability of primary health care in these communities and examine whether there are differences in patient outcomes with these nurse-physician co-led models of care.

The findings from this thesis can be used to inform health care policy in the province and identify current needs within family medicine. The rate of physician turnover in NL remains high, especially in rural regions. This may suggest that there is a need to focus on the retention of family doctors in the province, but findings from this project also suggest that there may be a need to explore other models of primary care delivery. Regions of the province with no family doctors often fared as well as regions with good retention of their family doctors. These regions are serviced by a combination of registered nurses, nurse practitioners, and visiting FPs. This model of care could be expanded to other areas of the province that experience high levels of FP turnover, as there is evidence that this model delivers good quality primary care. Future research could incorporate the availability of other modes of primary care delivery, such as telemedicine, as well as the inclusion of diabetes educators on health care teams. Examining a broad depiction of health service characteristics and availability would allow for the identification of important attributes of primary care for patients with diabetes.

NL experiences high rates of physician turnover and it is necessary to understand how this affects patients with chronic conditions who rely on primary care for disease management. This study depicted the state of diabetes in NL and provided mixed support for the relationship between FP turnover and health outcomes for patients with diabetes in

NL. This study was limited by the availability of data, but the results provide direction for future research studies and evidence for the value of primary care models that do not include a permanent primary care physician. More research is needed in this field, but the research conducted within this thesis provides a foundation for future studies on this topic.

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Appendices

Appendix A: Description and Sources of Variables

Table A-1

Description and Source of Variables Included in Study

Variable	Description	Source
Study ID	Unique patient identification number.	Appears in all datasets; used for linkage
Age	Patient's age in years, as of the end of the fiscal year.	Chronic Disease Registry
Sex	Patient's sex, as recorded in Medical Care Plan (MCP) file. Two nominal categories: male or female only.	Chronic Disease Registry
Health Authority	Regional Health Authority in which the patient resides. Four nominal categories: Eastern, Central, Western, or Labrador-Grenfell Health.	Chronic Disease Registry
Standard Geographical Classification (SGC)	SGC of patient's place of residence. Reported at the level of census subdivision (CSD)	Chronic Disease Registry
Diabetes case year	The fiscal year in which the patient was identified as having diabetes and added to the registry.	Chronic Disease Registry
Case source	The source of diabetes diagnosis. Three nominal categories: lab only, Canadian Chronic Disease Surveillance System (CCDSS) only, or both (both definitions were met).	Chronic Disease Registry
Year of death	If applicable, the fiscal year in which the patient died.	Chronic Disease Registry
Test collection date	Date lab sample was taken.	MEDITECH
Test name	Name of the lab test performed — three nominal categories: HbA_{1c}, LDL-C, or UACR.	MEDITECH
Test value	Numeric result of the lab test.	MEDITECH
Care episode type	Type of hospitalization care episode. Three nominal categories: acute care, surgical day care, or chronic care/nursing home/long-term care/personal care home/community care/family care.	Provincial Discharge Abstract Database
Admission date	Date of admission.	Provincial Discharge Abstract Database
Discharge date	Date of discharge.	Provincial Discharge Abstract Database
Family physician turnover	Rate of turnover of family physicians, calculated at the geographic level of economic zone.	Physician and Medical Practice Database
Number of family physicians per 1,000 population	The number of family physicians in an economic zone divided by the Census population of the economic zone.	Physician and Medical Practice Database

Appendix B: Health Research Ethics Board Approval Letter

NEWFOUNDLAND AND LABRADOR
HREB
HEALTH RESEARCH ETHICS BOARD

Research Ethics Office
Suite 200, Eastern Trust Building
95 Bonaventure Avenue
St. John's, NL
A1B 2X5

March 12, 2020

Dear Mr Buote:

Researcher Portal File # 20201457
Reference # 2019.261

RE: Factors associated with glycemic control, hospitalizations, and mortality among Newfoundland and Labrador residents with diabetes mellitus

Your application was reviewed by a subcommittee under the direction of the HREB and your response was reviewed by the Chair under the direction of the HREB and the following decision was rendered:

X	Approval
	Approval subject to changes
	Rejection

Ethics approval is granted for one year effective March 12, 2020. This ethics approval will be reported to the board at the next scheduled HREB meeting.

This is to confirm that the HREB reviewed and approved or acknowledged the following documents (as indicated):

- Application, approved
- Research proposal, approved
- Signed variable list, approved
- Emails with NLCHI acknowledging receipt of variable list, acknowledged
- Letter of Acknowledgement from Data Custodian, acknowledged

Please note the following:

- This ethics approval will lapse on March 12, 2021. It is your responsibility to ensure that the Ethics Renewal form is submitted prior to the renewal date.
- This is your ethics approval only. Organizational approval may also be required. It is your responsibility to seek the necessary organizational approvals.
- Modifications of the study are not permitted without prior approval from the HREB. Request for modification to the study must be outlined on the relevant Event Form available on the Researcher Portal website.
- Though this research has received HREB approval, you are responsible for the ethical conduct of this research.
- If you have any questions please contact info@hrea.ca or 709 777 6974.

The HREB operates according to the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS2), ICH Guidance E6: Good Clinical Practice Guidelines (GCP), the Health Research Ethics Authority Act (HREA Act) and applicable laws and regulations.

We wish you every success with your study.

Sincerely,

Dr Joy Maddigan, Chairperson
Health Research Ethics Board

You Have Received Ethics Approval, Now What?: HREB Reporting Requirements

Once a study has received ethics approval from the Health Research Ethics Board (HREB), there are still associated reporting requirements. In the conduct of approved research researchers are required to report to the HREB, in a timely manner, proposed changes from approved research that affect participants at any stage of the process. This includes, but is not limited to, changes to the consent form, changes to the tasks or interventions involved in the research, or changes to measures to protect privacy and confidentiality.

Any substantive change to the research should not be implemented prior to documented approval by the HREB, except when necessary to eliminate an immediate risk(s) to the participants. Below are examples of post approval documentation that must be submitted to the HREB:

Amendments

Any proposed change in the conduct of a study must be submitted to the HREB, and approved, before the change may be implemented. Such changes might include modification of recruitment procedures, inclusion or exclusion criteria, revised sample size, addition or deletion of study sites, changes to an intervention, consent forms, questionnaires or scripts, etc. If there are changes in project team members or changes to funding source(s)/sponsor(s), there are specific forms to complete to report this to the HREB.

Adverse Events

Serious and unanticipated adverse events that occur within Newfoundland and Labrador are required to be reported to the HREB. Such events may occur in both clinical trials and in other types of research, e.g. collapse during a rehabilitation program, emotional breakdown requiring follow up care during an interview, or breach of privacy during correspondence. Serious adverse events that are fatal or life-threatening are required to be reported to the HREB as soon as the research team is aware of the event.

Protocol Deviations

Deviations from an approved study protocol must be reported to the HREB. Changes that eliminate immediate hazards to participants do not require prior approval, but must be reported soon as reasonably possible.

Safety Reports

Safety reports providing information on all serious adverse events (SAEs) occurring in a clinical trial must be provided by the sponsor to the HREB, normally on a three or six monthly basis (i.e. in accordance with the specified reporting timelines that were outlined in the approved ethics application).

Investigator Brochure (IB) and Product Monograph (PM)

Throughout the course of a clinical trial, changes may be implemented to study documents. All revisions to approved study documents must be submitted to the HREB to ensure the record is up to date. If the revisions include new risk or safety information there may be a requirement to notify research participants.

Ethics Renewal/Study Closure

Ethics approval lasts for one year. Ethics renewal is required annually, on the anniversary of the date of the HREB notification of approval. Once data collection is no longer ongoing, a study closure form is required to be submitted to the HREB for the study to remain active or to be closed in good standing.

Appendix C: Newfoundland and Labrador Centre for Health Information Approval Letter

June 8, 2020

Richard Buote
Division of Community Health and Humanities
Memorial University

Dear Mr. Buote:

RE: Factors associated with glycemic control, hospitalizations, and mortality among Newfoundland and Labrador residents with diabetes mellitus
Our Reference *IM188870*

This is to advise you that the chair of the Centre's Secondary Uses Committee has reviewed your application to request Record-Level Information for Secondary Use. Having consulted with the chair, I authorize the disclosure of the requested data.

The approval of your application and use of the requested data is conditional upon the following:

- The data received must be used only for the purposes of this request. Any future uses and/or disclosures of the data provided must have HREB approval as well as approval from the Centre;
- Cell counts or statistics based on cell counts less than 5 are not published;
- The data must be stored on a Memorial University asset and must not be placed on a personal device;
- All members of the research team must comply with Memorial University's policies and procedures for privacy, security and data storage, and have signed an Oath of Confidentiality;
- At the end of the data retention period data must be disposed of by ensuring the drives on the device are appropriately sanitized (securely deleted or destroyed) prior to the disposal or repurposing of the system or any storage components;

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- If there are changes with the research study and/or research team then the Centre must provide approval for these changes. Any amendments or updated HREB approval(s) will be supplied to the Centre accordingly;

- Transfer of all record-level data to and from the Centre will be completed using the Centre's Managed File Transfer System (MFT);

- The Centre reserves the right to conduct an audit review of requestors who have been disclosed record-level data.

Please sign below and return to acknowledge you accept the above conditions of approval.

Signed:_____ Date: _____

On behalf of the Centre, I wish you every success with this research study.

Sincerely,

Blair White
Vice President, Corporate Services
NL Centre for Health Information
Cc: Donna Roche, Chair, Secondary Uses Committee

Newfoundland and Labrador Centre for Health Information
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70 O'Leary Avenue, St. John's, NL A1B 2C7
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Appendix D: Map of Economic Zones in Newfoundland and Labrador

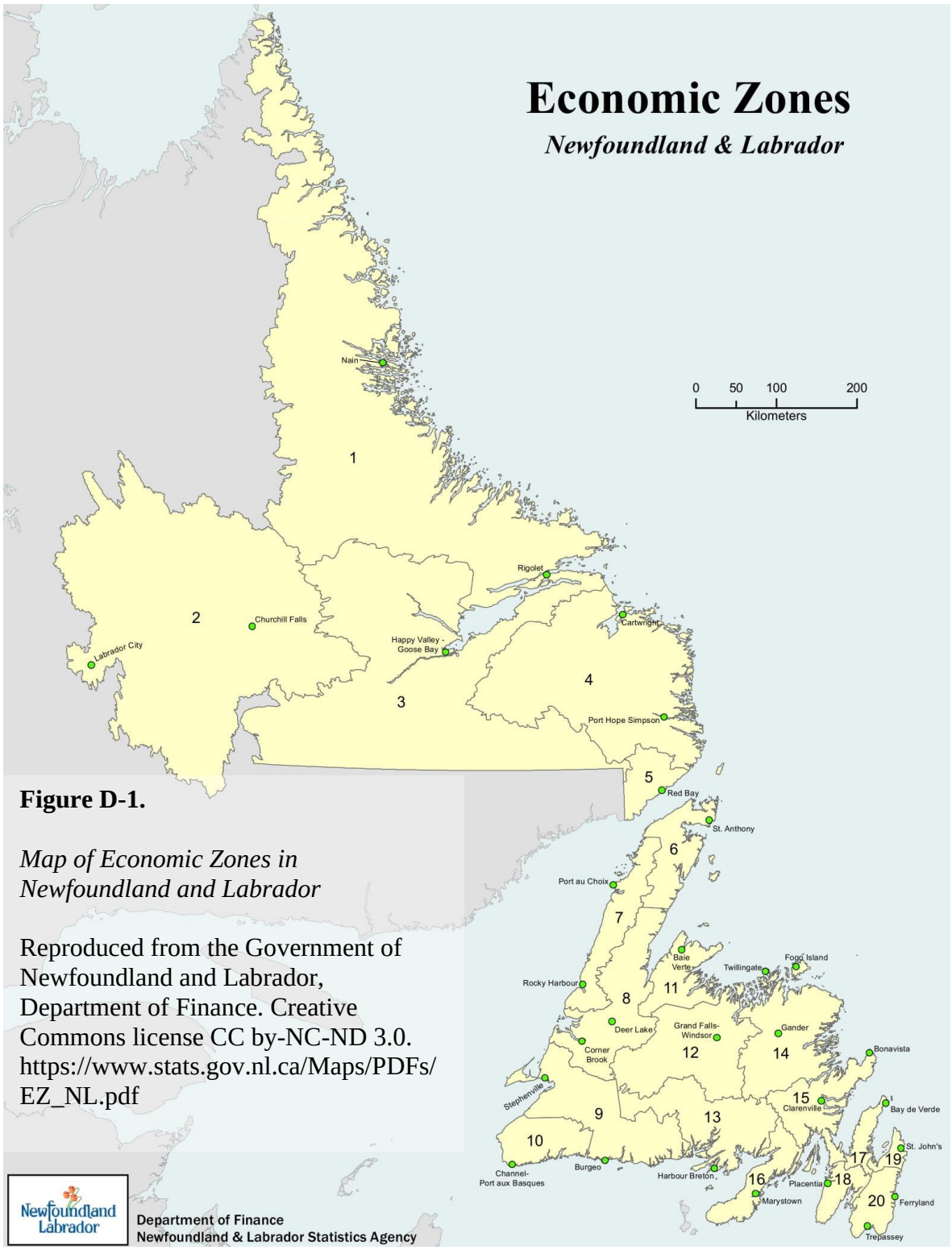

Figure D-1.

Map of Economic Zones in Newfoundland and Labrador

Reproduced from the Government of Newfoundland and Labrador, Department of Finance. Creative Commons license CC by-NC-ND 3.0. https://www.stats.gov.nl.ca/Maps/PDFs/EZ_NL.pdf

Appendix E: Comparison Between Individuals Who Did and Did Not Move Economic Zones Between 2011 and 2015.

Table E-1 shows the cross-tabulation of the level of turnover in the origin and destination economic zone for each individual who moved within the province between 2011/12 and 2015/16. There was a greater proportion of individuals living in an economic zone with high family physician (FP) turnover as compared to individuals living in an economic zone with low or moderate FP turnover. Additionally, a greater proportion of individuals who moved from an economic zone with moderate FP turnover moved to an economic zone with low FP turnover as compared to individuals moving from an economic zone with low or high FP turnover. Table E-2 shows the cross-tabulation of the rurality (i.e., urban or rural status) of the origin and destination census subdivision (CSD) for each individual who moved within the province. A greater proportion of individuals moved from an urban CSD to a rural CSD than from a rural CSD to another rural CSD. More information about the accessibility of health services within these regions would be required to understand whether the reason for the move was due to the availability of health services within the community.

To assess whether the study findings were influenced by individuals moving EZ zones (i.e., sicker, rural residents moving to larger urban centres as an example), outcomes of those who moved and those who did not move were compared. Table E-3 shows the Chi-square comparisons and the corresponding standardized differences between those who did and those who did not move economic zones between 2011 and 2015 on the three primary study outcomes (glycemic control, hospitalization, mortality). Individuals who moved between economic zones during the study period were excluded

from the sample. Although patients who moved within the province may have continued to see the same family doctor, this cannot be determined; therefore, these individuals were excluded from all analyses.

There was no statistically significant difference in the proportion of individuals meeting glycemic control targets between those who did and did not move economic zones. A greater proportion of individuals who moved economic zones were hospitalized (n = 858; 50.9%) but a smaller proportion died (n = 151; 9.0%), as compared to individuals who did not move (n = 17,710; 45.8% and n = 5,213; 13.5%, respectively). The standardized difference of the two statistically significant comparisons (hospitalization and mortality) was small (< 0.2), which suggests that the actual difference in hospitalization and mortality rate between individuals who did and individuals who did not move was minimal. These sensitivity analyses suggest that excluding these individuals may have introduced a bias within the sample selection. Individuals who moved within the province were more likely to have been hospitalized; therefore, some sicker individuals may have been excluded.

Table E-1

Cross Tabulation of Level of FP Turnover in Origin and Destination EZ for Individuals who Moved within the Province (n = 38,697)

	Moved from EZ with low turnover n (%)	Moved from EZ with moderate turnover n (%)	Moved from EZ with high turnover n (%)	Moved from EZ with no FPs n (%)
Moved to EZ with low turnover	**152 (28.4)**	**448 (43.6)**	**27 (29.3)**	**8 (26.7)**
Moved to EZ with moderate turnover	**363 (67.9)**	**535 (52.0)**	**41 (44.6)**	**12 (40.0)**
Moved to EZ with high turnover	**17 (3.2)**	**34 (3.3)**	**21 (22.8)**	**5 (16.7)**
Moved to EZ with no FPs	**3 (0.6)**	**11 (1.1)**	**3 (3.3)**	**5 (16.7)**

EZ – economic zone; FP – family physicians
shading indicates that the level of FP turnover remained the same following the move

Table E-2

Cross Tabulation of CSD Origin and Destination for Individuals who Moved within the Province (n = 38,697)

	Moved from an urban CSD n (%)	**Moved from a rural CSD n (%)**
Moved to an urban CSD	**186 (32.9)**	**543 (48.6)**
Moved to a rural CSD	**379 (67.1)**	**574 (51.4)**

CSD – census subdivision

Table E-3

Comparison of Individuals Who Did and Who Did Not Move Economic Zones Between 2011-2015 (n = 38,697)

Variable	**Did not move EZ n (%)**	**Moved EZ n (%)**	**Chi square (p-value)**	**Standard Difference (95% CI)**
TOTAL	**38,697 (100.0)**	**1,685 (100.0)**		
Glycemic control*			1.137 (p = 0.286)	0.027 (-0.022 – 0.075)
Off-target	27,437 (70.9)	1,215 (72.1)		
On-target	11,260 (29.1)	470 (27.9)		
Hospitalization			17.269 (p < 0.0001)	0.103 (0.054 – 0.152)
Was hospitalized	17,710 (45.8)	858 (50.9)		
Was not hospitalized	20,987 (54.2)	827 (49.1)		
Mortality			28.483 (p < 0.0001)	0.143 (0.094 – 0.192)
Died	5,213 (13.5)	151 (9.0)		
Lived	33,485 (86.5)	1,534 (91.0)		

EZ – economic zone
* - individuals with zero tests are coded as 'did not meet.'

Appendix F: Comparison between Individuals Who Were Identified as Having Diabetes by Combined Case Definition to Individuals Who Were Identified as Having Diabetes by CCDSS Case Definition Alone.

Table F-1 presents a comparison of characteristics between individuals who were identified as having diabetes according to the CCDSS case definition of diabetes and those who were retained as the sample for this study, that is, individuals who met the laboratory case definition alone or combined laboratory and CCDSS case definition (henceforth, combined case definition). According to the CCDSS definition, a person is considered to have diabetes if they "have at least one hospitalization record or at least two physician claims in a two-year period with an ICD code for diabetes" (Public Health Agency of Canada, 2015, p. 3). Within the CCDSS case definition, lab tests for glycemia are not used to indicate the presence of diabetes. Individuals identified by the CCDSS definition alone were excluded from the study sample to avoid bias. Potential bias would have been introduced in two ways. Hospitalization was an outcome of interest, and using hospitalization as an outcome and as a selection criterion may have biased this outcome. Further, the CCDSS case definition only identifies those with hospitalization or physician billing data; therefore, this case definition would under-represent individuals whose FP did not submit billing data. Because many non-fee-for-service physicians work in rural regions, and individuals residing in rural regions of the province are older, the decision was made to exclude individuals identified by the CCDSS case definition alone. The following sensitivity analyses were performed to determine whether the exclusion of these individuals may have affected the results of this study.

Overall, 38,697 individuals were included as the sample for this study and 8,574 were excluded, as they were identified as having diabetes according to the CCDSS definition alone. A greater proportion of the combined case definition group were male (n = 19,307; 49.9%) and living in a rural region (n = 21,771; 56.1%), as compared to the CCDDS-only group (n = 4,055; 47.3% male, n = 4,599; 53.6% rural). A greater proportion of the combined group were in the 65-79 (n = 17,139; 44.3%) and 50-64 (n = 11,077; 28.6%) years age group, as compared to the CCDSS-only group (n = 3,108; 36.2% and n = 1,943; 22.7%, respectively). A greater proportion of individuals identified as having diabetes by the combined case definition resided in an economic zone with less than one FP per 1,000 population (n = 5,596; 14.5%) and less than one acute care bed per 1,000 population (n = 2,608; 6.7%), as compared to individuals in the CCDSS-only group (n = 1,101; 12.8% and n = 526; 6.1% respectively). A greater proportion of individuals in the combined group lived in an economic zone with high FP turnover (n = 1,297; 3.4%) as compared to the CCDSS-only group (n = 203; 2.4%). A smaller proportion of individuals in the combined group met the recommended HbA_{1c} level (n = 11,260; 29.1%), as compared to the CCDSS-only group (n = 4,973; 58.0%). Conversely, a greater proportion of individuals in the combined group met the recommended level for LDL-C (n = 14,211; 36.7%) and UACR (n = 14,522; 37.5%), as compared to the CCDSS-only group (n = 1,292; 15.1% and n = 1,306; 15.2%). A greater proportion of the individuals in the combined group met recommended testing frequency for HbA_{1c} (n = 6,186; 16.0%), LDL-C (n = 12,590; 32.5%), and UACR (n = 3,212; 8.3%), as compared to the CCDSS-only group (n = 152; 1.8%, n = 1,423; 16.6%, and n = 135; 1.6%). There was no

Table F-1

Comparison of Study Sample to Individuals Identified as Having Diabetes by CCDSS Case Definition Alone (n = 38,697)

Variable	Combined Case Definition n (%)	CCDSS-only n (%)	Standard Difference (95% CI)
TOTAL	**38,697 (100.0)**	**8,574 (100.0)**	
Predisposing factors			
Sex			0.052 (0.029 – 0.075)
Female	19,390 (50.1)	4,519 (52.7)	
Male	19,307 (49.9)	4,055 (47.3)	
Age (years)			0.313 (0.289 – 0.336)
20-34	550 (1.4)	173 (2.0)	
35-49	2,814 (7.3)	714 (8.3)	
50-64	11,077 (28.6)	1,943 (22.7)	
65-79	17,139 (44.3)	3,108 (36.2)	
80+	7,117 (18.4)	2,636 (30.7)	
Enabling factors			
Rurality			0.05 (0.026 – 0.073)
Rural	21,771 (56.1)	4,599 (53.6)	
Urban	16,986 (43.9)	3,975 (46.4)	
Number of FPs per 1,000 pop.			0.059 (0.035 – 0.082)
<1.0	5,596 (14.5)	1,101 (12.8)	
1.0-1.25	14,880 (38.5)	3,498 (40.8)	
>1.25	18,221 (47.1)	3,975 (46.4)	
Physician turnover			0.101 (0.077 – 0.124)
Low (0-≤25)	15,962 (41.2)	3,566 (41.6)	
Moderate (>25-≤50)	21,189 (54.8)	4,793 (55.9)	
High (>50-100)	1,297 (3.4)	203 (2.4)	
No FPs in EZ	249 (0.6)	12 (0.1)	
Acute care beds per 1,000 population			0.061 (0.038 – 0.084)
0-1 bed	2,608 (6.7)	526 (6.1)	
> 1-2 beds	4,562 (11.8)	911 (10.6)	
> 2-3 beds	13,285 (34.3)	3,161 (36.9)	
3+ beds	18,242 (47.1)	3,976 (46.4)	
Need factors			
HbA1c mean level*			0.609 (0.586 – 0.633)
Did not meet CPG	27,437 (70.9)	3,601 (42.0)	
Met CPG	11,260 (29.1)	4,973 (58.0)	
LDL-C mean*			0.510 (0.487 – 0.534)
Did not meet CPG	24,486 (63.3)	7,282 (84.9)	
Met CPG	14,211 (36.7)	1,292 (15.1)	
UACR median*			0.523 (0.499 – 0.547)
Did not meet CPG	24,175 (62.5)	7,268 (84.8)	
Met CPG	14,522 (37.5)	1,306 (15.2)	
Process variables			
HbA1c testing frequency			1.086 (1.061 – 1.110)
Did not meet CPG	31,061 (80.3)	4,953 (57.8)	
Met CPG	6,186 (16.0)	152 (1.8)	
Did not receive any tests	1,450 (3.7)	3,469 (40.5)	
LDL-C testing frequency			0.670 (0.646 – 0.694)
Did not meet CPG	23,202 (60.0)	4,479 (52.2)	
Met CPG	12,590 (32.5)	1,423 (16.6)	
Did not receive any tests	2,905 (7.5)	2,672 (31.2)	
UACR testing frequency			1.028 (1.003 – 1.052)
Did not meet CPG	23,274 (60.1)	1,847 (21.5)	
Met CPG	3,212 (8.3)	135 (1.6)	
Did not receive any tests	12,211 (31.6)	6,592 (76.9)	
Outcomes			
Glycemic control*			0.609 (0.586 – 0.633)
Off-target	27,437 (70.9)	3,601 (42.0)	
On-target	11,260 (29.1)	4,973 (58.0)	
Hospitalization			0.02 (-0.003 – 0.044)
Was hospitalized	17,710 (45.8)	4,010 (46.8)	
Was not hospitalized	20,987 (54.2)	4,564 (53.2)	
Mortality			0.352 (0.328 – 0.375)
Died	5,212 (13.5)	2,353 (27.4)	
Lived	33,485 (86.5)	6,221 (72.6)	

FP – family physician; EZ – economic zone; HbA1c – glycated hemoglobin; LDL-C – low-density lipoprotein cholesterol; UACR – urine albumin-to-creatinine ratio; CPG – Clinical Practice Guideline

* - individuals with zero tests are coded as 'did not meet.'

difference between the combined and CCDSS case definition groups in likelihood of hospitalization. A smaller proportion of individuals in the combined group met the glycemic control outcome (HbA_{1c} level on-target [n = 11,260; 29.1%]), as compared to the CCDSS-only group (n = 4,973; 58.0%). A smaller proportion of individuals in the combined group died (n = 5,212; 13.5%) during the study period (2011-2015), as compared to the CCDSS-only group (n = 2,353; 27.4%).

Standardized differences were calculated to determine the effect size of each comparison. The standardized difference of five of the statistically significant comparisons (sex, rurality, number of FPs per 1,000 population, acute care beds per 1,000 population, FP turnover) was low (< 0.2), suggesting that although the difference was significant, the actual difference was minimal. Many of the comparisons had a moderate standardized difference (approximately 0.5), including age, HbA_{1c} (glycemic control), LDL-C, and UACR average level, LDL-C testing frequency, and mortality. Two comparisons (HbA_{1c} and UACR testing frequency) had large standardized differences, suggesting that the actual difference between the combined and CCDSS-only groups on these variables was substantial.

The results of this analysis suggest that the rate of death among the CCDSS-only group was much higher than the retained sample, which may be attributed to the relatively high proportion of individuals in this group who were 80 years and older. The analysis showed that around 40% of the people in the CCDSS-only group did not receive any HbA_{1c} tests during the study period, which is much higher than the study sample. Conversely, 58% of the CCDSS-only group had an average HbA_{1c} value of $\leq 7.0\%$, suggesting that almost all the individuals within the CCDSS-only group who received

tests were meeting the recommended target level. This indicates that some people with diabetes who had good glycemic control may have been excluded, thereby increasing the proportion of individuals within the sample with poor glycemic control. One plausible for the high proportion of individuals with an HbA_{1c} level on-target is that the CCDSS-only case definition includes a high percentage of long-term care residents. These individuals would be older and have an increased likelihood of death. In a long-term care setting, healthcare providers are often less concerned with stringent blood glucose management, especially when patients have other health conditions, such as frailty or cancer, and reduced life expectancy (Osman et al., 2016). This may be a contributing factor to the relatively low frequency of HbA_{1c} testing within this group.

Table F-2 compares individuals identified as having diabetes by the combined, laboratory-, and CCDSS-only case definitions. There were 36,686 individuals identified as having diabetes by the combined case definition, while 2,011 were identified by the laboratory case definition alone (laboratory-only), and 8,574 were identified by the CCDSS case definition alone (CCDSS-only). These groups were compared using a Chi-square pairwise analysis, corrected for multiple comparisons. The combined group had a greater proportion of males (n = 18,308; 49.9%) as compared to the CCDSS-only group (n = 4,055; 47.3%). The three different case definition groups statistically differed on the proportion of individuals within age groups. The CCDSS-only group had the greatest proportion of individuals in the oldest (80+) age group (n = 2,636; 30.7%), while the combined case definition group had the greatest proportion of individuals in the youngest age group (20-34 years) (n = 535; 1.5%). Similarly, all three groups differed on the

Table F-2

Comparison of Individuals Identified as Having Diabetes by Combined, CCDSS-only, and Laboratory-only Case Definitions (n = 38,697)

Variable	Combined Case Definition n (%)	Laboratory-only n (%)	CCDSS-only n (%)	Pairwise comparisons
TOTAL	**36,686 (100.0)**	**2,011 (100.0)**	**8,574 (100.0)**	
Predisposing factors				
Sex				b
Female	18,378 (50.1)	1,012 (50.3)	4,519 (52.7)	
Male	18,308 (49.9)	999 (49.7)	4,055 (47.3)	
Age (years)				a, b, c
20-34	535 (1.5)	15 (0.7)	173 (2.0)	
35-49	2,637 (7.2)	177 (8.8)	714 (8.3)	
50-64	10,442 (28.5)	635 (31.6)	1,943 (22.7)	
65-79	16,329 (44.5)	810 (40.3)	3,108 (36.2)	
80+	6,743 (18.4)	374 (18.6)	2,636 (30.7)	
Enabling factors				
Rurality				a, b, c
Rural	20,249 (55.2)	1,462 (72.7)	4,599 (53.6)	
Urban	16,437 (44.8)	549 (27.3)	3,975 (46.4)	
Number of FPs per 1,000 pop.				a, c
<1.0	5,036 (13.7)	560 (27.8)	1,101 (12.8)	
1.0-1.25	14,173 (38.6)	707 (35.2)	3,498 (40.8)	
>1.25	17,477 (47.6)	744 (37.0)	3,975 (46.4)	
Physician turnover				a, c
Low (0-≤25)	15,389 (41.9)	573 (28.5)	3,566 (41.6)	
Moderate (>25-≤50)	20,085 (54.7)	1,104 (54.9)	4,793 (55.9)	
High (>50-100)	1,054 (2.9)	243 (12.1)	203 (2.4)	
No FPs in EZ	158 (0.4)	91 (4.5)	12 (0.1)	
Acute care beds per 1,000 population				a, c
0-1 bed	2,421 (6.6)	187 (9.3)	526 (6.1)	
> 1-2 beds	4,110 (11.2)	452 (22.5)	911 (10.6)	
> 2-3 beds	12,647 (34.5)	638 (31.7)	3,161 (36.9)	
3+ beds	17,508 (47.7)	734 (36.5)	3,976 (46.4)	
Need factors				
HbA1c mean level*				a, b, c
Did not meet CPG	26,394 (71.9)	1,043 (51.9)	3,601 (42.0)	
Met CPG	10,292 (28.1)	968 (48.1)	4,973 (58.0)	
LDL-C mean*				b, c
Did not meet CPG	22,979 (62.6)	1,507 (74.9)	7,282 (84.9)	
Met CPG	13,707 (37.4)	504 (25.1)	1,292 (15.1)	
UACR median*				a, b, c
Did not meet CPG	22,907 (62.4)	1,268 (63.1)	7,268 (84.8)	
Met CPG	13,779 (37.6)	743 (36.9)	1,306 (15.2)	
Process variables				
HbA1c testing frequency				b, c
Did not meet CPG	29,464 (80.3)	1,597 (79.7)	4,953 (57.8)	
Met CPG	5,955 (16.2)	231 (11.5)	152 (1.8)	
Did not receive any tests	1,267 (3.5)	183 (9.1)	3,469 (40.5)	
LDL-C testing frequency				b, c
Did not meet CPG	22,029 (60.0)	1,173 (58.3)	4,479 (52.2)	
Met CPG	11,932 (32.5)	658 (32.7)	1,423 (16.6)	
Did not receive any tests	2,725 (7.4)	180 (9.0)	2,672 (31.2)	
UACR testing frequency				a, b, c
Did not meet CPG	22,163 (60.4)	1,111 (55.2)	1,847 (21.5)	
Met CPG	3,113 (8.5)	99 (4.9)	135 (1.6)	
Did not receive any tests	11,410 (31.1)	801 (39.8)	6,592 (76.9)	
Outcomes				
Glycemic control*				a, b, c
Off-target	26,394 (71.9)	1,043 (51.9)	3,601 (42.0)	
On-target	10,292 (28.1)	968 (48.1)	4,973 (58.0)	
Hospitalization				a, c
Was hospitalized	17,224 (46.9)	486 (24.2)	4,010 (46.8)	
Was not hospitalized	19,462 (53.1)	1,525 (75.8)	4,564 (53.2)	
Mortality				a, b, c
Died	5,023 (13.7)	189 (9.4)	2,353 (27.4)	
Lived	31,663 (86.3)	1,822 (90.6)	6,221 (72.6)	

FP – family physician; EZ – economic zone; HbA1c – glycated hemoglobin; LDL-C – low-density lipoprotein cholesterol; UACR – urine albumin-to-creatinine ratio; CPG – Clinical Practice Guideline

* - individuals with zero tests are coded as 'did not meet.'

a, b, c indicate the results of multiple pairwise comparisons between case definitions ($p < 0.05$, Bonferroni correction applied)

a – combined and laboratory-only case definitions differ

b – combined and CCDSS-only case definitions differ

c – Laboratory and CCDSS-only case definitions differ

proportion of individuals residing in rural regions. The laboratory-only group had the greatest proportion of individuals residing in a rural region (n = 1,462; 72.7%), while the CCDSS-only group had the greatest proportion of individuals residing in an urban region (n = 3,975; 46.4%). The laboratory-only group differed from the combined and CCDSS-only groups on the number of FPs and number of acute care beds per 1,000 population, as well as level of FP turnover within the economic zone. A greater proportion of individuals identified as having diabetes by the laboratory-only case definition lived in an economic zone with fewer than one FP (n = 560; 27.8%) and 0-1 acute care beds (n = 187; 9.3%), per 1,000 population and lived in an economic zone with high FP turnover (n = 243; 12.1%). All groups differed on the proportion of individuals who met the recommended target level for HbA_{1c} and UACR. A greater proportion of individuals identified as having diabetes by the CCDSS case definition only met the recommended target for HbA_{1c} (n = 4,973; 58.0%), while individuals identified by the combined case definition were less likely to meet recommended HbA_{1c} levels (n = 10,292; 28.1%). Conversely, a greater proportion of individuals identified as having diabetes by the combined case definition met the recommended target for UACR (n = 13,779; 37.6%), while individuals identified by the CCDSS case definition only were less likely to meet recommended UACR levels (n = 1,306; 15.2%). The CCDSS-only group had a smaller proportion of individuals who met the recommended target for LDL-C (n = 1,292; 15.1%) than the combined and laboratory-only case definition groups. Similarly, the CCDSS-only group had a smaller proportion of individuals who met the recommended target testing frequency for HbA_{1c} (n = 152; 1.8%), LDL-C (n = 1,423; 16.6), and UACR (n = 135; 1.6%). The combined and laboratory-only case definition groups differed on the

proportion of individuals meeting the recommended testing frequency for UACR. A greater proportion of individuals in the combined case definition group met the recommended frequency for UACR (n = 3,113; 8.5%). Regarding the outcomes, all three groups differed on the outcomes of glycemic control and mortality. The CCDSS-only group had the greatest proportion of individuals who met the recommended target level for HbA_{1c} (n = 4,973; 58.0%) and the greatest proportion of individuals who died (n = 2,353; 27.4%). Individuals identified as having diabetes by the laboratory case definition alone had the smallest proportion of individuals who died (n = 189; 9.4%), while the combined case definition group had the greatest proportion of individuals who did not meet the recommended HbA_{1c} target level (n = 26,394; 71.9%). Finally, the laboratory-only case definition differed from the combined and CCDSS-only case definition groups on the proportion of hospitalized individuals. The laboratory-only group had a smaller proportion of hospitalized individuals (n = 486; 24.2%) than the other two case definition groups.

In summary, the results of this analysis suggest that the CCDSS-only group significantly differed from the combined case definition group, particularly in age, mortality, and testing levels and frequencies. The testing patterns among the CCDSS-only group were substantially different from the study sample, suggesting that the CCDSS-only group is markedly different from the sample and the exclusion is appropriate. I posit that there may be a high proportion of long-term care residents in this group, although using the available data, this cannot be determined for certain.

Appendix G: Multicollinearity Testing.

The relationships between covariates were tested for the presence of multicollinearity. The results of the multicollinearity tests are presented in Table G-1. All variables are categorical; therefore, the effect size of the Chi-square analysis was examined to identify potential collinearity (i.e., Cramér's V or phi coefficient). Cramér's V and phi coefficient indicate the association between two categorical variables. Similar to using Pearson's r to identify multicollinearity, associations with a Cramér's V or phi coefficient greater than 0.7 were considered colinear and redundant (Tabachnick & Fidell, 2012). FP turnover is collinear with rurality, and because FP turnover is the primary predictor of interest, rurality was considered to be redundant and was excluded from the models. The number of FPs per 1,000 population and the number of acute care beds per 1,000 population were highly collinear; therefore, one of the two variables needed to be excluded. FP turnover has a weaker relationship with the number of acute care beds per 1,000 population than the number of FPs per 1,000 population; therefore, the number of FPs per 1,000 population was not used within the regression analyses.

Table G-1

Results of Multicollinearity Testing of Covariates

	1	2	3	4	5	6	7	8	9	10	11
1 Sex											
2 Age (years)	0.024										
3 Rurality	0.079	0.058									
4 Number of FPs per 1,000 pop.	0.024	0.043	0.712								
5 Physician turnover	0.027	0.037	0.717	0.608							
6 Acute care beds per 1,000 pop.	0.021	0.029	0.714	0.881	0.537						
7 HbA1c mean level	0.012	0.138	0.018	0.021	0.028	0.031					
8 LDL-C mean level	0.089	0.118	0.057	0.063	0.063	0.049	0.001				
9 UACR mean level	0.044	0.193	0.038	0.047	0.045	0.061	0.028	0.028			
10 HbA1c testing frequency	0.018	0.087	0.017	0.050	0.058	0.068	0.132	0.157	0.158		
11 LDL-C testing frequency	0.025	0.152	0.039	0.049	0.053	0.068	0.095	0.227	0.220	0.424	
12 UACR testing frequency	0.030	0.123	0.043	0.040	0.052	0.063	0.066	0.132	0.528	0.277	0.290

Appendix H: Process of Care Outcomes

H-1 HbA_{1c} Testing Frequency

Table H-1 presents the characteristics of individuals who did not meet the Diabetes Canada CPG recommended HbA_{1c} testing frequency (n = 32,511; 84.0% of the study population), as compared to individuals who met the testing frequency recommendation (n = 6,186; 16.0% of the study population). A greater proportion of individuals who did not receive the recommended number of tests were male (n = 16,312; 50.2%) and living in a rural community (n = 18,311; 56.3%), as compared to individuals who received the recommended number of tests (n = 2,995; 48.4% and n = 3,400; 55.0%, respectively). When examining age groups, a greater proportion of individuals who did not meet the recommended HbA_{1c} testing frequency were in the youngest and oldest groups, with 1.5% (n = 487) in the 20-34 years age group and 18.8% (n = 6,124) in the 80+ age group, as compared to individuals who did not meet the recommended HbA_{1c} testing frequency (n = 63; 1.0% and n = 993; 16.1%, respectively). A greater proportion of individuals did not meet the recommended HbA_{1c} testing frequency lived in an economic zone with <1.0 (n = 4,924; 15.1%) and 1.0-1.25 (n = 12,728; 39.1%) family physicians (FPs) per 1,000 population, as compared to individuals who received the recommended number of HbA_{1c} tests (n = 672; 10.9% and n = 2,152; 34.8%, respectively). Similarly, a greater proportion of individuals who did not receive the recommended HbA_{1c} testing lived in an economic zone with 0-1 acute care beds per 1,000 population (n = 2,338; 7.2%), as compared to individuals who met the recommended HbA_{1c} testing frequency (n = 270; 4.4%). A smaller proportion of individuals who did not

Table H-1

Bivariate Analysis of HbA1c Testing Frequency and Characteristics of Adults with Diabetes in Newfoundland and Labrador (n = 38,697)

Variable	Did not meet CPG n (%)	Met CPG n (%)	p-value	Standard difference (95% CI)
TOTAL	**32,511 (100.0)**	**6,186 (100.0)**		
Predisposing factors				
Sex			0.012	0.035 (0.008 – 0.062)
Female	16,199 (49.8)	3,204 (51.6)		
Male	16,312 (50.2)	2,995 (48.4)		
Age (years)			< 0.0001	0.208 (0.181 – 0.236)
20-34	487 (1.5)	63 (1.0)		
35-49	2,548 (7.8)	266 (4.3)		
50-64	9,391 (28.9)	1,686 (27.3)		
65-79	13,961 (42.9)	3,178 (51.4)		
80+	6,124 (18.8)	993 (16.1)		
Enabling factors				
Rurality			0.049	0.027 (0.000 – 0.055)
Rural	18,311 (56.3)	3,400 (55.0)		
Urban	14,200 (43.7)	2,786 (45.0)		
Number of FPs per 1,000 pop.			< 0.0001	0.186 (0.158 – 0.213)
<1.0	4,924 (15.1)	672 (10.9)		
1.0-1.25	12,728 (39.1)	2,152 (34.8)		
>1.25	14,859 (45.7)	3,362 (54.3)		
Physician turnover			< 0.0001	0.190 (0.163 – 0.217)
Low (0-≤25)	13,206 (40.6)	2,756 (44.6)		
Moderate (>25-≤50)	18,166 (55.9)	3,023 (48.9)		
High (>50-100)	993 (3.1)	304 (4.9)		
No FPs in EZ	146 (0.4)	103 (1.7)		
Acute care beds per 1,000 population			< 0.0001	0.232 (0.205 – 0.259)
0 - 1 beds	2,338 (7.2)	270 (4.4)		
> 1 - 2 beds	3,995 (12.3)	567 (9.2)		
> 2 - 3 beds	11,414 (35.1)	1,871 (30.2)		
3+	14,764 (45.4)	3,478 (56.2)		
Need factors				
HbA1c mean*			< 0.0001	0.078 (0.051 – 0.105)
Did not meet CPG	22,870 (70.3)	4,567 (73.8)		
Met CPG	9,641 (29.7)	1,619 (26.2)		
LDL-C mean*			< 0.0001	0.283 (0.256 – 0.311)
Did not meet CPG	21,290 (65.5)	3,196 (51.7)		
Met CPG	11,221 (34.5)	2,990 (48.3)		
UACR median*			< 0.0001	0.187 (0.160 – 0.215)
Did not meet CPG	20,785 (63.9)	3,390 (54.8)		
Met CPG	11,726 (36.1)	2,796 (45.2)		
Process variables				
LDL-C testing frequency			< 0.0001	0.820 (0.792 – 0.848)
Did not meet CPG	21,187 (65.2)	2,015 (32.6)		
Met CPG	8,619 (26.5)	3,971 (64.2)		
Did not receive any tests	2,705 (8.3)	200 (3.2)		
UACR testing frequency			< 0.0001	0.674 (0.647 – 0.702)
Did not meet CPG	19,727 (60.7)	3,547 (57.3)		
Met CPG	1,609 (4.9)	1,603 (25.9)		
Did not receive any tests	11,175 (34.4)	1,036 (16.7)		

FP – family physician; EZ – economic zone; HbA1c – glycated hemoglobin; LDL-C – low-density lipoprotein cholesterol; UACR – urine albumin-to-creatinine ratio; CPG – Clinical Practice Guidelines; CI – confidence interval

* - individuals with zero tests are coded as 'did not meet.'

receive the recommended number of HbA_{1c} tests lived in an economic zone with low (n = 13,206; 40.6%) and high (n = 993; 3.1%) FP turnover, as compared to individuals who received the recommended number of HbA_{1c} tests (n = 2,756; 44.6% and n = 304; 4.9%, respectively). A greater proportion of individuals who did not meet the HbA_{1c} testing frequency recommendations had a mean HbA_{1c} that met the CPG target level (n = 9,641; 29.7%), as compared to individuals who met the testing frequency recommendation (n = 1,619; 26.2%). Conversely, a lower proportion of individuals who did not meet the recommended testing frequency for HbA_{1c} had a mean LDL-C (n = 11,221; 34.5%) and median UACR (n = 11,726; 36.1%) value that met the CPG target as compared to individuals who met the recommended HbA_{1c} testing frequency (n = 2,990; 48.3% and n = 2,796; 45.2% respectively). Finally, a lower proportion of individuals who did not meet the recommended HbA_{1c} testing frequency met the recommended testing frequency for LDL-C (n = 8,619; 26.5%) and UACR (n = 1,609; 4.9%), as compared to individuals who met the recommended testing frequency for HbA_{1c} (n = 3,971; 64.2% and n = 1,603; 25.9% respectively).

Standardized differences were calculated to determine the effect size of each comparison. All the comparisons were statistically significant. Many of the standardized differences were small (< 0.2), including sex, rurality, number of FPs per 1,000 population, FP turnover, and average HbA_{1c} and UACR level. For these variables, the actual difference between individuals who did and did not meet recommended HbA_{1c} testing frequency was minimal. Three of the other comparisons had low to moderate (0.2 – 0.5) standardized differences (age, number of acute care beds per 1,000 population, and

LDL-C mean level), and two of the comparison had moderate to large (> 0.5) standardized differences (LDL-C and UACR testing frequency).

H-1.1 Multivariable Logistic Regression of Predictors of HbA1c Testing Frequency

Table H-2 shows the results of the binomial logistic regression predicting the likelihood of meeting the recommended testing frequency for HbA_{1c} while controlling for other covariates. Turnover was associated with HbA_{1c} testing frequency. Individuals living in economic zones with moderate or high turnover had an increased likelihood of meeting HbA_{1c} testing frequency recommendations (OR = 1.514, 95% CI 1.376 – 1.666; OR = 2.533, 95% CI 2.186 – 2.936, respectively), as compared to individuals living in an economic zone with low turnover. Additionally, individuals living in an economic zone with no FPs were 16.992 (95% CI 12.430 – 23.229) times more likely to have met the recommended HbA_{1c} testing frequency than individuals living in an economic zone with low turnover. Age and number of acute care beds per 1,000 population were significant predictors of meeting recommended HbA_{1c} testing frequency. Individuals aged 50-64 and 65-79 years were more likely to have met recommended testing frequency (OR = 1.443; 95% CI 1.102 – 1.889 and OR = 1.857; 95% CI 1.422 – 2.425 respectively), as compared to individuals aged 20-34. Males were less likely to have received the recommended HbA_{1c} testing frequency than females (OR = 0.916; 95% CI 0.866 – 0.968). Individuals living in economic zones with 1-2, 2-3, or 3+ acute care beds per 1,000 population were more likely to have received the recommended testing frequency than individuals living in an economic zone with 0-1 acute care beds. Age-sex interaction was tested but not significant and not included in the final regression model.

This model was statistically significant ($\chi^2(11) = 893.502$, $p < 0.0001$), passed the Hosmer Lemeshow test ($p > 0.05$), and explained 3.9% of the variance in meeting the recommended testing frequency for LDL-C (Nagelkerke R^2). Residuals were examined, and 1,264 (3.3%) cases had a standard deviation greater than two. Cook's distance was calculated, and none of the cases had a value greater than one; therefore, all cases were retained.

Table H-2

Predictors of Meeting Recommended HbA1c Testing Frequency among Adults with Diabetes in Newfoundland and Labrador (n = 38,697)

	β	Standard error	Wald Chi-square	df	p-value	Odds ratio	Odds ratio 95% CI
Constant	-3.522	0.163	465.632	1	< 0.0001	0.030	
Age (years)							
20-34						1.00	
35-49	-0.202	0.150	1.823	1	0.177	0.817	(0.610 - 1.095)
50-64	0.367	0.137	7.130	1	0.008	1.443	(1.102 - 1.889)
65-79	0.619	0.136	20.641	1	< 0.0001	1.857	(1.422 - 2.425)
80+	0.252	0.139	3.271	1	0.071	1.286	(0.979 - 1.689)
Sex							
Female							
Male	-0.088	0.028	9.804	1	0.002	0.916	(0.866 – 0.968)
Number of acute care beds per 1,000 pop.							
0 - 1 bed						1.00	
> 1 - 2 beds	0.812	0.095	73.038	1	< 0.0001	2.253	(1.870 – 2.714)
> 2 - 3 beds	0.897	0.087	105.186	1	< 0.0001	2.451	(2.065 – 2.910)
3+	1.605	0.090	314.635	1	< 0.0001	4.979	(4.170 -5.945)
Turnover							
Low turnover						1.00	
Moderate turnover	0.415	0.049	71.954	1	< 0.0001	1.514	(1.376 - 1.666)
High turnover	0.930	0.075	152.595	1	< 0.0001	2.533	(2.186 - 2.936)
No FPs in EZ	2.833	0.160	315.332	1	< 0.0001	16.992	(12.430 - 23.229)

df – degrees of freedom; OR – odds ratio; CI – confidence interval; FP – family physician; EZ – economic zone; HbA1c – glycated hemoglobin

H-2 LDL-C Testing Frequency

Table H-3 compares the characteristics of individuals who did not meet the Diabetes Canada CPG recommendations for LDL-C testing frequency (n = 26,107; 67.5% of the study population) to individuals who did meet the Diabetes Canada CPG recommendations for LDL-C testing frequency (n = 12,590; 32.5% of the study population). A greater proportion of individuals who did not meet the recommended testing frequency were female (n = 13,282; 50.9%) and living in a rural census subdivision (n = 14,998; 57.4%), as compared to individuals who met the recommended testing frequency (n = 6,108; 48.5% and n = 6,713; 53.3%). A larger percentage of individuals who did not meet the recommended testing frequency were in the oldest and youngest age groups, with a greater proportion of individuals in the 20-34 (n = 488; 1.9%) and the 80+ years (n = 5,260; 20.1%) age groups, as compared to individuals who met the recommended testing frequency (n = 62; 0.5% and 1,857; 14.7%, respectively). There was a smaller proportion of individuals who did not meet the recommended testing frequency for LDL-C living in economic zones with more than 1.25 FPs (n = 11,668; 44.7%) and more than three acute care beds (n = 11,610; 44.5%) per 1,000 population, as compared to individuals who met the recommended testing frequency guideline (n = 6,553; 52.0% and n = 6,632; 52.7%, respectively). Individuals who did and did not meet the CPG recommendations for LDL-C testing frequency differed on the proportions of individuals within each turnover group. A smaller proportion of those who did not meet CPG testing recommendations lived in an economic zone with low turnover (n = 10,114; 38.7%) as compared to individuals who met CPG recommendation (n = 5,848; 46.4%). A lower proportion of individuals who did not meet the recommended testing frequency for

Table H-3

Bivariate Analysis of LDL-C Testing Frequency and Characteristics of Adults with Diabetes in Newfoundland and Labrador (n = 38,697)

Variable	Did not meet CPG n (%)	Met CPG n (%)	p-value	Standard difference 95% CI
TOTAL	**26,107 (100.0)**	**12,590 (100.0)**		
Predisposing factors				
Sex			< 0.0001	0.047 (0.026 – 0.068)
Female	13,282 (50.9)	6,108 (48.5)		
Male	12,825 (49.1)	6,482 (51.5)		
Age (years)			< 0.0001	0.305 (0.283 – 0.326)
20-34	488 (1.9)	62 (0.5)		
35-49	2,250 (8.6)	564 (4.5)		
50-64	7,572 (29.0)	3,505 (27.8)		
65-79	10,537 (40.4)	6,602 (52.4)		
80+	5,260 (20.1)	1,857 (14.7)		
Enabling factors				
Rurality			< 0.0001	0.083 (0.062 – 0.104)
Rural	14,998 (57.4)	6,713 (53.3)		
Urban	11,109 (42.6)	5,877 (46.7)		
Number of FPs per 1,000 pop.			< 0.0001	0.148 (0.127 – 0.169)
<1.0	3,968 (15.2)	1,628 (12.9)		
1.0-1.25	10,471 (40.1)	4,409 (35.0)		
>1.25	11,668 (44.7)	6,553 (52.0)		
Physician turnover			< 0.0001	0.159 (0.137 – 0.180)
Low (0-≤25)	10,114 (38.7)	5,848 (46.4)		
Moderate (>25-≤50)	14,895 (57.1)	6,294 (50.0)		
High (>50-100)	937 (3.6)	360 (2.9)		
No FPs in EZ	161 (0.6)	88 (0.7)		
Acute care beds per 1,000 population			< 0.0001	0.189 (0.168 – 0.211)
0-1 beds	1,989 (7.6)	619 (4.9)		
1-2 beds	3,056 (11.7)	1,506 (12.0)		
2-3 beds	9,452 (36.2)	3,833 (30.4)		
3+ beds	11,610 (44.5)	6,632 (52.7)		
Need factors				
HbA1c mean*			< 0.0001	0.163 (0.142 – 0.184)
Did not meet CPG	19,145 (73.3)	8,292 (65.9)		
Met CPG	6,962 (26.7)	4,298 (34.1)		
LDL-C mean*			< 0.0001	0.226 (0.205 – 0.247)
Did not meet CPG	17,448 (66.8)	7,038 (55.9)		
Met CPG	8,659 (33.2)	5,552 (44.1)		
UACR median*			< 0.0001	0.324 (0.302 – 0.345)
Did not meet CPG	17,641 (67.6)	6,534 (51.9)		
Met CPG	8,466 (32.4)	6,056 (48.1)		
Process variables				
HbA1c testing frequency			< 0.0001	0.657 (0.635 – 0.679)
Did not meet CPG	22,502 (86.2)	8,559 (68.0)		
Met CPG	2,215 (8.5)	3,971 (31.5)		
Did not receive any tests	1,390 (5.3)	60 (0.5)		
UACR testing frequency			< 0.0001	0.605 (0.583 – 0.627)
Did not meet CPG	15,581 (59.7)	7,693 (61.1)		
Met CPG	813 (3.1)	2,399 (19.1)		
Did not receive any tests	9,713 (37.2)	2,498 (19.8)		

FP – family physician; EZ – economic zone; HbA1c – glycated hemoglobin; LDL-C – low-density lipoprotein cholesterol; UACR – urine albumin-to-creatinine ratio; CPG – Clinical Practice Guidelines; CI – confidence interval
* - individuals with zero tests are coded as 'did not meet.'

LDL-C met the Diabetes Canada recommended target value for HbA_{1c} (n = 6,962; 26.7%), LDL-C (n = 8,659; 33.2%), and UACR (n = 8,466; 32.4%), as compared to individuals who met the recommended LDL-C testing frequency (n = 4,298; 34.1%, n = 5,552; 44.1%, n = 6,056; 48.1%, respectively). Similarly, a lower proportion of individuals who did not meet the recommended testing frequency for LDL-C met the recommended testing frequency for HbA_{1c} (n = 2,215; 8.5%) and UACR (n = 813; 3.1%), as compared to individuals who met the recommended testing frequency for LDL-C (n = 3,971; 31.5% and n = 2,399; 19.1% respectively).

All the comparisons were statistically significant. Around half of the standardized differences were small (< 0.2), including sex, rurality, number of FPs and number of acute care beds per 1,000 population, FP turnover, and average HbA_{1c} level, suggesting that although these comparisons were significant, the actual difference in the proportion was minimal. Three of the other comparisons had low to moderate standardized differences (0.2 – 0.5 [age and average LDL-C and UACR level]), and two of the comparisons had moderate to large (> 0.5) standardized differences (HbA1c and UACR testing frequency).

H-2.1 Multivariable Logistic Regression of Predictors of LDL-C Testing Frequency

Table H-4 shows the results of the binomial logistic regression predicting the likelihood of meeting the recommended testing frequency for LDL-C while controlling for other covariates. Turnover was associated with meeting the recommended LDL-C testing frequency. Individuals living in an economic zone with moderate (OR = 0.904; 95% CI 0.834 – 0.979) or high (OR = 0.843; 95% CI 0.736 – 0.966) FP turnover were less likely to have met the recommended testing frequency, while individuals living in an

economic zone with no FPs were more likely (OR = 1.773; 95% CI 1.326 – 2.372) to have met recommended testing frequency, as compared to individuals living in an economic zone with low turnover. The interaction between age and sex and the number of acute care beds were associated with meeting LDL-C testing frequency. Overall, older people (i.e., people aged 35-49, 50-64, 64-79, 80+ years) were more likely to have received the recommended number of LDL-C tests, but this relationship interacted with the sex of the individual. People living in economic zones with 1-2, 2-3, and 3+ acute care beds all had a greater likelihood of meeting the recommended testing frequency for LDL-C than individuals living in an economic zone with 0-1 acute care beds.

This model was statistically significant ($\chi^2(15) = 1162.065$, $p < 0.0001$), passed the Hosmer Lemeshow test ($p > 0.05$), and explained 4.1% of the variance in meeting the recommended testing frequency for LDL-C (Nagelkerke R^2). Residuals were examined, and 80 (0.21%) cases had a standard deviation greater than two. Cook's distance was calculated, and none of the cases had a value greater than one; therefore, all were retained.

Table H-4

Predictors of Meeting Recommended LDL-C Testing Frequency among Adults with Diabetes in Newfoundland and Labrador (n = 38,697)

	β	Standard error	Wald Chi-square	df	p-value	Odds ratio	Odds ratio 95% CI
Constant	-1.919	0.135	201.101	1	< 0.0001	0.147	
Sex							
Female						1.00	
Male	-0.120	0.270	0.196	1	0.658	0.887	(0.522 – 1.507)
Age (years)							
20-34						1.00	
35-49	0.619	0.200	9.566	1	0.002	1.856	(1.254 – 2.747)
50-64	1.268	0.191	44.040	1	< 0.0001	3.553	(2.443 – 5.167)
65-79	1.594	0.190	70.292	1	< 0.0001	4.922	(3.391 – 7.145)
80+	0.922	0.192	23.016	1	< 0.0001	2.514	(1.725 – 3.664)
Age*Sex							
Male*35-49	0.192	0.286	0.448	1	0.503	1.211	(0.691 – 2.123)
Male*50-64	0.154	0.273	0.318	1	0.573	1.167	(0.683 – 1.994)
Male*65-79	0.141	0.272	0.270	1	0.603	1.152	(0.676 – 1.964)
Male*80+	0.347	0.276	1.583	1	0.208	1.415	(0.824 – 2.429)
Acute care beds per 1,000 pop.							
0 - 1 bed						1.00	
> 1 - 2 beds	0.513	0.061	71.257	1	< 0.0001	1.670	(1.483 – 1.881)
> 2 - 3 beds	0.321	0.055	33.792	1	< 0.0001	1.379	(1.237 – 1.536)
3+	0.614	0.062	98.744	1	< 0.0001	1.847	(1.637 – 2.085)
Turnover							
Low turnover						1.00	
Moderate turnover	-0.101	0.041	6.072	1	0.014	0.904	(0.834 - 0.979)
High turnover	-0.170	0.069	6.032	1	0.014	0.843	(0.736 - 0.966)
No FPs in EZ	0.573	0.148	14.900	1	< 0.001	1.773	(1.326 - 2.372)

df – degrees of freedom; OR – odds ratio; CI – confidence interval; FP – family physician; EZ – economic zone; LDL-C – low-density lipoprotein cholesterol

H-3 UACR Testing Frequency

Table H-5 presents the characteristics of individuals who did not meet the Diabetes Canada CPG recommendations for UACR testing frequency (n = 35,485; 91.7% of the study population), as compared to individuals who met the recommended testing frequency (n = 3,212; 8.3% of the study population). A greater proportion of individuals

who did not meet the CPG recommendations for UACR testing frequency were female (n = 17,942; 50.6%) and living in a rural census subdivision (n = 20,089; 56.6%), as compared to individuals who met the testing frequency recommendations (n = 1,448; 45.1% and n = 1,622; 50.5%). A greater proportion of individuals who did not meet the testing frequency recommendation were aged 20-34 (n = 517; 1.5%), 35-49 (2,641; 7.4%), and 80+ (6,678; 18.8%) years, as compared to those who met the recommendation. A smaller proportion of individuals who did not meet the recommended UACR testing frequency lived in an economic zone with 1.25+ FPs (n = 16,486; 46.5%) and 3+ acute care beds per 1,000 population (n = 16,465; 46.4%), than those who met the recommended frequency (n = 1,735; 54.0% and n = 1,777; 55.3%, respectively). Individuals who did and did not meet the CPG for UACR testing frequency differed on the proportion of individuals within the four turnover groups. A smaller proportion of individuals who did not meet CPG recommendations lived in an economic zone with low turnover (n = 14,421; 40.6%), as compared to individuals who met the CPG recommendations (n = 1,541; 48.0%). A smaller proportion of individuals who did not meet the recommended frequency for UACR testing did not meet the recommended mean HbA_{1c} value (n = 10,459; 29.5%) compared to individuals who did receive the recommended number of UACR tests (n = 801; 24.9%). A lower proportion of individuals who did not meet the recommended UACR testing frequency met the Diabetes Canada CPG recommended LDL-C level (n = 12,649; 35.6%) compared to individuals who met the recommended UACR testing frequency (n = 1,563; 48.7%). Similarly, a lower proportion of individuals who did not meet the recommended UACR testing frequency met the Diabetes Canada CPG recommended UACR level (n = 12,959;

36.5%), as compared to individuals who met the recommended UACR testing frequency (n = 1,563; 48.7%). A smaller proportion of individuals who did not meet the recommended UACR testing frequency met the recommended testing frequency for HbA_{1c} (n = 4,583; 12.9%) and LDL-C (n = 10,191; 28.7%), as compared to individuals who met the recommended testing frequency for UACR (n = 1,603; 49.9% and n = 2,399; 74.7% respectively).

All the comparisons were statistically significant. Around half of the standardized differences were small (< 0.2), including sex, age, rurality, number of FPs per 1,000 population, FP turnover, and average HbA_{1c} level, suggesting that the actual difference in the proportions between groups was minimal. Three of the other comparisons had low to moderate standardized differences (0.2 – 0.5 [number of acute care beds per 1,000 population and average LDL-C and UACR level]), and two of the comparisons had large (> 0.8) standardized differences (HbA_{1c} and LDL-C testing frequency).

Table H-5

Bivariate Analysis of UACR Testing Frequency and Characteristics of Adults with Diabetes in Newfoundland and Labrador (n = 38,697)

Variable	Did not meet CPG n (%)	Met CPG n (%)	p-value	Standard difference 95% CI
TOTAL	**35,485 (100.0)**	**3,212 (100.0)**		
Predisposing factors				
Sex			< 0.0001	0.110 (0.074 – 0.146)
Female	17,942 (50.6)	1,448 (45.1)		
Male	17,543 (49.4)	1,764 (54.9)		
Age (years)			< 0.0001	0.183 (0.147 – 0.219)
20-34	517 (1.5)	33 (1.0)		
35-49	2,641 (7.4)	173 (5.4)		
50-64	10,111 (28.5)	966 (30.1)		
65-79	15,538 (43.8)	1,601 (49.8)		
80+	6,678 (18.8)	439 (13.7)		
Enabling factors				
Rurality			< 0.0001	0.123 (0.087 – 0.159)
Rural	20,089 (56.6)	1,622 (50.5)		
Urban	15,396 (43.4)	1,590 (49.5)		
Number of FPs per 1,000 pop.			< 0.0001	0.174 (0.138 – 0.210)
<1.0	5,265 (14.8)	331 (10.3)		
1.0-1.25	13,734 (38.7)	1,146 (35.7)		
>1.25	16,486 (46.5)	1,735 (54.0)		
Physician turnover			< 0.0001	0.171 (0.135 – 0.208)
Low (0-≤25)	14,421 (40.6)	1,541 (48.0)		
Moderate (>25-≤50)	19,615 (55.3)	1,574 (49.0)		
High (>50-100)	1,232 (3.5)	65 (2.0)		
No FPs in EZ	217 (0.6)	32 (1.0)		
Acute care beds per 1,000 population			< 0.0001	0.239 (0.203 – 0.275)
0-1 beds	2,502 (7.1)	106 (3.3)		
1-2 beds	4,290 (12.1)	272 (8.5)		
2-3 beds	12,228 (34.5)	1,057 (32.9)		
3+ beds	16,465 (46.4)	1,777 (55.3)		
Need factors				
HbA1c mean*			< 0.0001	0.102 (0.066 – 0.138)
Did not meet CPG	25,026 (70.5)	2,411 (75.1)		
Met CPG	10,459 (29.5)	801 (24.9)		
LDL-C mean*			< 0.0001	0.265 (0.229 – 0.301)
Did not meet CPG	22,836 (64.4)	1,650 (51.4)		
Met CPG	12,649 (35.6)	1,562 (48.6)		
UACR median*			< 0.0001	0.247 (0.211 – 0.284)
Did not meet CPG	22,526 (63.5)	1,649 (51.3)		
Met CPG	12,959 (36.5)	1,563 (48.7)		
Process variables				
HbA1c testing frequency			< 0.0001	0.895 (0.858 - 0.932)
Did not meet CPG	29,461 (83.0)	1,600 (49.8)		
Met CPG	4,583 (12.9)	1,603 (49.9)		
Did not receive any tests	1,441 (4.1)	9 (0.3)		
LDL-C testing frequency			< 0.0001	1.041 (1.004 – 1.078)
Did not meet CPG	22,443 (63.2)	759 (23.6)		
Met CPG	10,191 (28.7)	2,399 (74.7)		
Did not receive any tests	2,851 (8.0)	54 (1.7)		

FP – family physician; EZ – economic zone; HbA1c – glycated hemoglobin; LDL-C – low-density lipoprotein cholesterol; UACR – urine albumin-to-creatinine ratio; CPG – Clinical Practice Guidelines; CI – confidence interval

* - individuals with zero tests are coded as 'did not meet.'

H-3.1 Multivariable Logistic Regression of Predictors of UACR Testing Frequency

Table H-6 shows the results of the binomial logistic regression predicting the likelihood of meeting the recommended testing frequency for UACR while controlling for other covariates. Turnover was associated with meeting the recommended UACR testing frequency. Individuals living in economic zones with high FP turnover were less likely to have met the recommended UACR testing frequency (OR = 0.718; 95% CI 0.552 – 0.934) than individuals living in low turnover economic zones. Conversely, individuals living in economic zones with no FPs were 4.477 times (95% CI 2.835 – 7.068) more likely to have met recommended testing frequency than individuals living in low turnover economic zones. Age, sex, and the number of acute care beds per 1,000 population were significant predictors of meeting UACR testing frequency. People older 50-64 and 65-79 were more likely to have met UACR testing frequency recommendations (OR = 1.567; 95% CI 1.095 – 2.243, OR = 1.711; 95% CI 1.198 – 2.443) than people aged 20-34. Males were more likely to have met the recommended UACR testing frequency than females (OR = 1.212; 95% CI 1.127 – 1.304). Finally, people living in economic zones with 1-2, 2-3, and 3+ acute care beds all had a higher likelihood of meeting the recommended UACR testing frequency than individuals living in an economic zone with 0-1 acute care beds. Age-sex interaction was tested but not significant and not included in the final regression model.

Table H-6

Predictors of Meeting Recommended UACR Testing Frequency among Adults with Diabetes in Newfoundland and Labrador (n = 38,697)

	β	Standard error	Wald Chi-square	df	p-value	Odds ratio	Odds ratio 95% CI
Constant	-3.897	0.225	300.399	1	< 0.0001	0.020	
Age (years)							
20-34						1.00	
35-49	0.064	0.196	0.105	1	0.746	1.066	(0.725 – 1.566)
50-64	0.449	0.183	6.019	1	0.014	1.567	(1.095 – 2.243)
65-79	0.537	0.182	8.710	1	0.003	1.711	(1.198 – 2.443)
80+	0.101	0.187	0.294	1	0.588	1.106	(0.767 – 1.595)
Sex							
Female						1.00	
Male	0.192	0.037	26.666	1	< 0.0001	1.212	(1.127 – 1.304)
Acute care beds per 1,000 pop.							
0 - 1 bed						1.00	
> 1 - 2 beds	0.606	0.136	19.914	1	< 0.0001	1.832	(1.404 – 2.391)
> 2 - 3 beds	0.915	0.125	53.859	1	< 0.0001	2.496	(1.955 – 3.187)
3+	1.176	0.133	78.276	1	< 0.0001	3.242	(2.498 – 4.207)
Turnover							
Low turnover						1.00	
Moderate turnover	0.028	0.069	0.168	1	0.682	1.029	(0.899 – 1.176)
High turnover	-0.331	0.134	6.081	1	0.014	0.718	(0.552 – 0.934)
No FPs in EZ	1.499	0.233	41.367	1	< 0.0001	4.477	(2.835 – 7.068)

df – degrees of freedom; OR – odds ratio; CI – confidence interval; FP – family physician; EZ – economic zone; UACR – urine albumin-to-creatinine ratio

This model was statistically significant ($\chi^2(14) = 333.040$, $p < 0.0001$), passed the Hosmer Lemeshow test ($p > 0.05$), and explained 2.0% of the variance in meeting the recommended testing frequency for LDL-C (Nagelkerke R^2). Residuals were examined, and 3,199 (8.2%) cases had a standard deviation greater than two. Cook's distance was calculated, and none of the cases had a value greater than one; therefore, all cases were retained.