Assessing the Impact of Fruits and Vegetable Consumption and Food Insecurity on Chronic Diseases in Canada

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Abstract

Chronic diseases such as cardiovascular disease, diabetes, cancer, and high blood pressure are leading causes of morbidity and mortality in Canada, accounting for 89% of deaths annually and imposing an economic burden of $190 billion each year. These conditions are closely linked to dietary patterns, yet fruit and vegetable consumption remains below the recommended 400 grams per day for many Canadians. Simultaneously, food insecurity affects 17.8% of Canadian households, representing approximately 8.7 million people, including 2.1 million children, with rates as high as 46% in territories like Nunavut, exacerbating health disparities.

This thesis analyzes the impact of fruit and vegetable consumption and food insecurity on chronic disease prevalence using Canadian Community Health Survey data (2004–2020). The study employs logistic regression models to assess these relationships at national and provincial levels, as well as across demographic and socioeconomic groups. Higher fruit and vegetable consumption at the national level was significantly linked to reduced chronic disease risks, including a 13.3% lower likelihood of developing high blood pressure across Canada. However, these effects varied across provinces, reflecting differences in dietary patterns. In Quebec, high fruit and vegetable intake reduced diabetes odds by 14%, whereas in Newfoundland, starchy vegetable consumption, such as potatoes and carrots, was associated with a 32.5% increase in cardiovascular disease risk, highlighting the regional impact of specific dietary habits on health outcomes. Food insecurity was significantly associated with poorer health outcomes, including higher prevalence rates of diabetes and hypertension. Food-insecure households were more likely to rely on nutrient-poor, calorie-dense foods, exacerbating chronic disease risks, particularly among low-income populations.

The findings underscore the need for targeted public health interventions to improve dietary habits and food access. Effective strategies, such as subsidies, school-based programs, community initiatives, and federally supported programs like Nutrition North Canada, can enhance fruit and vegetable intake, particularly in remote and underserved regions. Addressing these challenges is crucial to reducing chronic disease prevalence and improving population health outcomes across Canada.

Résumé

Les maladies chroniques comme les maladies cardiovasculaires, le diabète, le cancer et l'hypertension artérielle sont les principales causes de morbidité et de mortalité au Canada, représentant 89 % des décès chaque année et imposant un fardeau économique de 190 milliards de dollars annuel. Bien que ces conditions soient étroitement liées aux habitudes alimentaires, la consommation de fruits et de légumes reste inférieure aux 400 grammes recommandés par jour pour de nombreux Canadiens. Simultanément, l'insécurité alimentaire touche 17,8 % des ménages canadiens, ce qui représente environ 8,7 millions de personnes, dont 2,1 millions d'enfants, avec des taux pouvant atteindre 46 % dans des territoires comme le Nunavut, ce qui aggrave les disparités en matière de santé.

Cette thèse analyse l'impact de la consommation de fruits et de légumes et de l'insécurité alimentaire sur la prévalence des maladies chroniques à l'aide des données de l'Enquête sur la santé dans les collectivités canadiennes (2004-2020). L'étude utilise des modèles de régression logistique pour évaluer ces relations aux niveaux national et provincial, ainsi qu'entre les groupes démographiques et socio-économiques. Une consommation accrue de fruits et légumes à l'échelle nationale a été significativement liée à une réduction des risques de maladies chroniques, notamment une diminution de 13,3 % de la probabilité de développer une hypertension artérielle au Canada. Cependant, ces effets varient selon les provinces, reflétant des différences dans les habitudes alimentaires. Au Québec, une consommation élevée de fruits et légumes a réduit les risques de diabète de 14 %, tandis qu'à Terre-Neuve, la consommation de légumes féculents, comme les pommes de terre et les carottes, a été associée à une augmentation de 32,5 % du risque de maladie cardiovasculaire, soulignant l'impact régional des habitudes alimentaires spécifiques sur les résultats de santé. L'insécurité alimentaire a été significativement associée à des résultats sanitaires plus médiocres, notamment des taux de prévalence plus élevés de diabète et d'hypertension. Les ménages en situation d'insécurité alimentaire étaient plus susceptibles de dépendre d'aliments pauvres en nutriments et riches en calories, ce qui aggrave les risques de maladies chroniques, en particulier parmi les populations à faible revenu.

Les résultats soulignent la nécessité d'interventions en santé publique ciblées afin d'améliorer les habitudes alimentaires et l'accès à la nourriture. Des stratégies efficaces, telles que des subventions, des programmes en milieu scolaire, des initiatives communautaires et des programmes soutenus par le gouvernement fédéral comme Nutrition Nord Canada, peuvent

améliorer la consommation de fruits et légumes, en particulier dans les régions éloignées et mal desservies. Relever ces défis est essentiel afin de réduire la prévalence des maladies chroniques et d'améliorer les résultats en matière de santé de la population partout au Canada.

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Chapter 1 - Introduction

The rising prevalence of chronic diseases poses a significant challenge to public health systems globally. Imagine a future where simple dietary adjustments could significantly reduce the burden of these diseases, improving quality of life and reducing healthcare costs. This research embarks on a journey to explore how something as fundamental as access to fruits and vegetables and the security of food availability can transform health outcomes.

By addressing these critical issues, this thesis aims to contribute useful insights to the field of public health nutrition, ultimately guiding interventions that promote healthier lifestyles and equitable access to nutritious food. Through rigorous analysis and comprehensive exploration, this study will shed light on the intricate relationships between diet, food security, and chronic disease outcomes, paving the way for more effective and targeted public health strategies.

Chronic diseases, such as cardiovascular diseases, diabetes, cancer, and high blood pressure, present a significant public health challenge worldwide. Dietary habits and socioeconomic circumstances, especially food insecurity, have a significant impact on these disorders. Understanding the relationship between diet, food security, and chronic disease outcomes is critical for developing effective public health interventions.

1.1. Defining the Diet and Its Importance

The literature highlights the protective effects of fruits and vegetables against chronic diseases and the adverse impacts of food insecurity on health. A higher intake of fruits and vegetables is linked to a decreased prevalence of diseases including diabetes and heart disease. Diets rich in these foods are linked to reduced risks of hypertension, coronary heart disease, and stroke due to their high fiber content, antioxidants, and essential nutrients. However, the evidence for cancer prevention remains less consistent.

In contrast, food insecurity is linked to poorer health outcomes, such as greater prevalence of obesity, diabetes, and cardiovascular disease. Those who experience food insecurity frequently consume diets that are of lesser quality, consisting of foods that are high in calories but low in nutrients, which exacerbates these negative effects. Additionally, the psychological stress of food insecurity exacerbates poor health by promoting unhealthy coping behaviors and amplifying the physiological effects of inadequate nutrition.

1.1.1. What is a fruit and vegetable diet?

Consuming a range of fruits and vegetables is the main source of nourishment in a fruits and vegetables diet. Rich in vital vitamins, minerals, fibre, and antioxidants, this kind of diet is ideal for maintaining general health and preventing chronic diseases. Fruits and vegetables are typically low in calories and fat, making them an excellent choice for weight management and reducing the risk of obesity-related conditions. Incorporating a variety of colourful produce ensures that you get enough nutrients and phytochemicals, each with their own set of health advantages. Studies have consistently shown that diets high in fruits and vegetables are associated with a lower risk of conditions such as heart disease, hypertension, diabetes, and certain types of cancer. People can boost their immune systems, improve their nutritional status, and promote long-term health and well-being by making fruits and vegetables a priority.

1.1.2. Why are fruits and vegetables essential for human health?

Fruits and vegetables are crucial to human health due to their high content of essential nutrients like vitamins, minerals, fiber, and antioxidants. These nutrients support various bodily functions, including immune system health, digestion, and inflammation reduction. For instance, fiber helps maintain digestion, prevent constipation, regulate blood sugar levels, and lower cholesterol. Antioxidants found in fruits and vegetables protect against oxidative stress, reducing the risk of chronic diseases such as heart disease, cancer, and diabetes. Additionally, vitamins and minerals contribute to overall well-being, from skin health to vision. Regular consumption of a diverse range of fruits and vegetables is associated with better health outcomes and longevity.

Dietary habits strongly influence chronic disease development and management. Fruits and vegetables are known to protect against conditions like cardiovascular disease, diabetes, and certain cancers. Increased intake of these foods has been linked to lower risks of hypertension, heart disease, and stroke.

Fruits and vegetables also contain bioactive compounds such as vitamins C and E, beta-carotene, flavonoids, and phytochemicals, which reduce inflammation and oxidative stress—two key factors in chronic disease progression. For example, vitamin C, abundant in citrus fruits, acts as a powerful antioxidant, while beta-carotene, found in carrots and sweet potatoes, supports healthy vision and immune function.

The fiber in fruits and vegetables further contributes to lower risks of cardiovascular diseases and type 2 diabetes. It slows sugar absorption, preventing spikes in blood glucose, and

reduces cholesterol by promoting its excretion. This helps prevent conditions like atherosclerosis, where cholesterol buildup in the arteries leads to heart disease.

Obesity, a major risk factor for chronic diseases, can also be mitigated through increased fruit and vegetable consumption. These foods are low in calories and high in fiber, which promotes satiety and aids in weight management. A study from the Journal of the American Dietetic Association found that individuals who consumed more fruits and vegetables had lower body mass indices (BMIs) and a reduced likelihood of being overweight or obese. The high water content in many fruits and vegetables also contributes to a feeling of fullness, supporting healthy weight control.

This study focuses specifically on the role of fruit and vegetable consumption due to their unique and well-documented health benefits, such as reducing inflammation, improving metabolic health, and lowering chronic disease risks. While other components of a healthier diet, such as protein and healthy fats, are also essential for overall health, the scope of this research is deliberately narrowed to isolate the effects of fruit and vegetable consumption. This allows for a more detailed examination of their specific contributions to chronic disease prevention. Future research could explore how dietary components, such as protein, fats, and carbohydrates, interact with fruit and vegetable intake to provide a more comprehensive understanding of their combined impacts on health outcomes.

1.2. Burden of Chronic Diseases Globally and Nationally

1.2.1. Global Trends in Dietary Patterns

Global dietary patterns have shifted significantly in recent decades due to globalization and urbanization. Increased availability and affordability of ultra-processed, calorie-dense foods high in sugar, unhealthy fats, and salt have replaced traditional plant-based diets rich in fruits and vegetables. This trend, coupled with reduced physical activity due to sedentary lifestyles, has contributed to rising rates of obesity, cardiovascular diseases, diabetes, and other non-communicable diseases (NCDs). The World Health Organization (WHO) highlights that fruit and vegetable consumption remains below recommended levels in many regions, exacerbating these health challenges.

These dietary shifts are particularly pronounced in low and middle income countries, where rapid urbanization has transformed food environments, making processed foods more

accessible. As a result, chronic diseases have overtaken infectious diseases as the leading global health concerns, driven by changes in diet and socioeconomic conditions.

Fruits and vegetables, rich in antioxidants, fiber, vitamins, and minerals, play a critical role in preventing chronic diseases. In contrast, food insecurity increases reliance on less nutritious, affordable options, further elevating the risk of poor health outcomes.

1.2.2. Global Burden of Chronic Diseases

Chronic diseases, or non-communicable diseases (NCDs), are the leading cause of death globally, accounting for approximately 71% of all deaths—equivalent to 41 million annually. Cardiovascular diseases, cancers, respiratory diseases, and diabetes constitute the majority of NCD-related deaths, with cardiovascular diseases alone causing 17.9 million deaths each year. The rise in NCDs is largely driven by aging populations, unhealthy diets, physical inactivity, tobacco use, and excessive alcohol consumption. Health disparities are stark, as 85% of premature deaths (before age 70) from NCDs occur in low- and middle-income countries (The Lancet Global Health, 2019).

This burden is unevenly distributed. For instance, sub-Saharan Africa has experienced a surge in NCDs over the past two decades due to increasing cardiovascular risk factors such as hypertension, obesity, unhealthy diets, reduced physical activity, and air pollution.

Low fruit and vegetable consumption significantly contributes to the global disease burden, leading to an estimated 2.635 million deaths annually (Lock et al., 2005). Increasing daily intake to 600 grams could reduce the global disease burden by 1.8%. Specific reductions include a 31% decrease in ischemic heart disease, 19% in ischemic stroke, and notable reductions in stomach, esophageal, lung, and colorectal cancers by 19%, 20%, 12%, and 2%, respectively. Between 1990 and 2019, deaths and Disability-Adjusted Life Years (DALYs) linked to low fruit consumption increased by 31.5% and 27.4%, respectively (Global Burden of Disease Study, 2023).

The World Health Organization (WHO) recommends consuming more than 400 grams of fruits and vegetables daily to mitigate NCD risks and improve health outcomes (WHO, 2023). However, many regions still fall short. For instance, countries in the WHO European Region struggle with inadequate fruit and vegetable intake, reflecting the global challenge of improving dietary patterns (Centers for Disease Control and Prevention, 2023).

1.2.3. National burden of chronic diseases

The economic burden of chronic diseases in Canada is substantial, impacting both direct healthcare costs and broader societal expenses. For instance, inadequate adherence to dietary recommendations for eight key food groups contributes CAD $13.8 billion annually—$5.1 billion in direct healthcare costs and $8.7 billion in indirect costs (Lieffers et al., 2018). In Ontario, risk factors such as tobacco smoking ($7.0 billion), alcohol consumption ($4.5 billion), physical inactivity ($2.6 billion), and unhealthy eating ($5.6 billion, including $1.8 billion from inadequate vegetable and fruit consumption) significantly strain the economy (Public Health Ontario, 2019).

Seniors are disproportionately affected, with 76% reporting at least one chronic condition in 2007 (Canadian Institute for Health Information, 2011). Seniors account for 44% of publicly funded healthcare costs, largely due to this high prevalence. Chronic diseases like cardiovascular disease impose immense costs; for example, cardiovascular disease alone cost Canada $22.2 billion in 2000, with $7.6 billion attributed to direct healthcare expenses (Canadian Institute for Health Information, 2011). These trends align with global patterns, where chronic diseases represent a significant economic and public health challenge.

1.2.4. Non-Communicable Diseases in Canada

Non-communicable diseases (NCDs)—including cardiovascular diseases, diabetes, cancer, high blood pressure, and obesity—are the leading causes of morbidity and mortality in Canada, accounting for approximately 89% of all deaths. Cardiovascular diseases and cancers are particularly prevalent, underscoring the urgent need for effective prevention and management strategies.

Globally, NCDs are a major barrier to development, causing significant mortality and economic productivity losses (Beaglehole, 2011). According to the WHO, NCDs were responsible for nearly two-thirds of global deaths in 2008, with cardiovascular diseases, cancers, type 2 diabetes, and chronic lung diseases leading the list (Alwan, 2011). In Canada, two in five individuals over the age of 12 have at least one NCD, and 80% are at risk of developing one. Annually, 177,800 Canadians are diagnosed with cancer, over 1.6 million live with heart disease or stroke, and more than 3 million have chronic respiratory diseases. These conditions collectively account for roughly two-thirds of Canadian deaths, including 75,000 annual deaths

from cancer alone. Individuals with diabetes face twice the mortality risk compared to those without the condition.

The economic impact of NCDs is profound, with direct healthcare costs amounting to $68 billion annually and indirect costs—stemming from lost income and reduced productivity—reaching $122 billion. In 2010, the total economic burden of chronic diseases in Canada was estimated at $190 billion annually, a figure expected to rise with increasing prevalence among working-age Canadians. Conditions like diabetes, which affect 0.4% of individuals aged 35-44 and 1.2% of those aged 45-64 annually, further exacerbate healthcare costs and productivity losses (Public Health Agency of Canada, 2013).

Comprehensive strategies for prevention, early detection, and effective management are critical to reducing the burden of NCDs. Without such efforts, their escalating health and economic consequences will continue to impact individuals and the broader Canadian society.

1.2.5. Chronic disease statistics in Canada

Cardiovascular diseases (CVDs), including heart disease and stroke, are among the most prevalent chronic conditions in Canada. In 2021, an estimated 2.6 million Canadians were living with heart disease, and about 70,000 deaths annually were attributed to cardiovascular conditions. CVDs are responsible for approximately 1 in 3 deaths across the country. Risk factors such as poor diet, lack of physical activity, and high rates of obesity contribute significantly to these figures. (Government of Canada, 2021).

Diabetes is another major chronic disease in Canada. In 2021, about 3.3 million Canadians (or 8.8% of the population) were living with diagnosed diabetes, with the prevalence expected to rise. Diabetes contributes to the development of cardiovascular diseases, kidney failure, and other health complications. It is estimated that individuals with diabetes have a mortality rate nearly twice as high as those without the condition. (Statistics Canada, 2021).

Cancer is the leading cause of death in Canada. Each year, approximately 247,100 new cancer cases and 88,100 cancer deaths in Canada for 2024. The most common types of cancer are lung, breast, colorectal, and prostate cancers. While advancements in early detection and treatment have improved survival rates, cancer remains responsible for nearly 30% of all deaths in the country. (Canadian Cancer Society, 2024).

1.3. Government Policies and Public Health Interventions

1.3.1. Canada's Food Guide and Public Health Policies

The Canadian government has taken significant steps to combat diet-related chronic diseases through the implementation of the Healthy Eating Strategy. This comprehensive initiative aims to facilitate healthier dietary choices for Canadians, primarily through the revision of Canada's Food Guide. Key elements of the strategy include improving nutrition information, enhancing food quality, and increasing the availability and accessibility of healthy food options (Bacon et al., 2019). Furthermore, the strategy encompasses measures such as reducing sodium and trans fats in foods and restricting the marketing of unhealthy foods.

Data from the Canadian Community Health Survey highlights the urgency of these measures, particularly in northern Canada, where there is a high prevalence of chronic diseases like arthritis, high blood pressure, and asthma. Obesity and smoking are also notably prevalent in these regions, posing additional risk factors for these conditions (Lix et al., 2010). The Healthy Eating Strategy underscores the necessity of strong policy interventions to effectively address the major health issues arising from unhealthy eating patterns, demonstrating the government's commitment to influencing individual dietary behaviors towards better health outcomes (Bacon et al., 2019). This strategy includes revising Canada's Food Guide, improving label information, reducing sodium and trans fats in food, and restricting marketing of unhealthy foods.

Canada has recognized the critical role that diet plays in preventing and managing chronic diseases, leading to the implementation of several national public health initiatives. These initiatives are designed to promote healthier eating habits and address food insecurity, which is a key factor contributing to the rising rates of chronic diseases like heart disease, diabetes, and obesity.

Canada's Food Guide

The 2019 update to Canada's Food Guide is a cornerstone of the country's public health strategy to encourage healthier dietary patterns. It emphasizes the importance of consuming a variety of fruits, vegetables, whole grains, and plant-based proteins while discouraging the intake of processed and high-sugar foods. By promoting nutrient-dense choices, the guide aims to reduce the prevalence of diet-related health conditions and improve overall health outcomes. This national tool is instrumental in helping Canadians make informed food choices that can prevent chronic diseases (Health Canada).

Canada's Healthy Eating Strategy

The Healthy Eating Strategy is another key initiative aimed at improving dietary habits across Canada. This strategy includes measures like front-of-package labeling to help consumers make healthier choices, restricting the marketing of unhealthy foods to children, and reducing sodium, sugar, and saturated fat content in processed foods. By influencing public dietary behaviors, the strategy seeks to address rising rates of chronic diseases and promote healthier lifestyles (Government of Canada, *Healthy Eating Strategy*).

Public Health Initiatives on Food Security

The Food Policy for Canada is a broad public health initiative aimed at improving food security by ensuring that all Canadians have access to safe, healthy, and culturally appropriate food. This policy acknowledges that food insecurity increases the risk of chronic diseases by leading individuals to consume lower-cost, nutrient-poor foods. Addressing food insecurity is essential for reducing the prevalence of chronic conditions, particularly in vulnerable populations (Agriculture and Agri-Food Canada).

Community-Based Initiatives

In addition to national programs, various provinces and municipalities have introduced community-based initiatives to promote healthy eating and access to nutritious foods. Programs like Farm to School bring locally grown fruits and vegetables into schools to encourage healthier eating habits among children. Other efforts, such as urban community gardens and food banks, aim to increase access to fresh produce in underserved areas, further supporting public health goals.

Government of Canada Initiatives

Beyond these efforts, the Canadian Food Policy Advisory Council provides guidance on food system issues, including reducing food insecurity. The Local Food Infrastructure Fund supports local food projects to improve access to healthy foods for at-risk populations. Additionally, the Nutrition North Canada (NNC) program continues to ensure that residents of isolated and remote communities have access to nutritious food. The government is also developing a National Children's Food Policy and a national children's nutritious meal program to further combat food insecurity and promote healthy eating among young Canadians (Government of Canada, *Zero Hunger*).

1.3.2. Nutrition North Canada

Addressing food security, particularly in remote and northern communities, the Canadian government launched Nutrition North Canada. This initiative subsidizes the cost of nutritious foods such as fresh fruits and vegetables for residents in isolated regions, where food insecurity is a persistent issue. By improving access to healthy foods, this program targets poor dietary habits and aims to reduce the risk of chronic diseases in vulnerable populations (Government of Canada, *Nutrition North Canada*).

1.4. Problem Statement

The dual issues of inadequate fruit and vegetable consumption and food insecurity present significant barriers to managing and preventing chronic diseases. Despite the well-documented benefits of fruits and vegetables and the detrimental effects of food insecurity, there remains a significant gap in understanding the specific relationships between these factors and chronic disease outcomes within the Canadian context. Previous studies have primarily focused on the general population or specific subgroups, leaving a comprehensive analysis that includes diverse demographic and socioeconomic variables relatively unexplored. This gap hinders the development of targeted public health strategies and interventions that could effectively address these issues.

This research aims to bridge this gap by utilizing data from the Canadian Community Health Survey (CCHS) from 2004 to 2020 to explore how fruit and vegetable consumption and food insecurity affect chronic disease outcomes. By employing logistic regression models, this study will quantify the impact of dietary habits and food security status on the prevalence of chronic diseases, providing valuable insights for public health policies and practices.

1.5. Research Questions

This research seeks to answer two primary questions: How does the consumption of fruits and vegetables affect the prevalence of chronic diseases such as cardiovascular diseases, high blood pressure, diabetes, and cancer? How does the consumption of fruits and vegetables affect the prevalence of chronic diseases such as cardiovascular diseases, diabetes, cancer, and obesity? Additionally, how does food insecurity impact the prevalence of chronic diseases? These questions aim to uncover the intricate connections between diet, food security, and chronic disease outcomes, providing insights into potential areas for public health intervention.

1.6. Objectives

This research aims to explore the impact of dietary habits and food insecurity on chronic disease outcomes. It seeks to quantify how fruit and vegetable consumption influences the prevalence of chronic diseases, such as cardiovascular diseases, diabetes, cancer, and obesity. Additionally, the study will examine the effects of food insecurity on the management and progression of these conditions. A key focus will be identifying demographic and socioeconomic factors that may moderate or mediate these relationships, offering a deeper understanding of how different populations are affected. Based on the findings, the research will provide policy recommendations to inform public health strategies and interventions aimed at reducing chronic disease burden and promoting equitable access to nutritious food.

1.7. Research Methodology

Utilizing the CCHS data from 2004 to 2020, this study employs logistic regression models to analyze the impact of fruit and vegetable consumption and food insecurity on chronic diseases. The dependent variables include chronic disease status (presence or absence of cardiovascular diseases, diabetes, cancer, and high blood pressure), while the independent variables are daily fruit and vegetable consumption and levels of food insecurity. Control variables such as age, sex, income, education, and lifestyle behaviors (e.g., alcohol consumption) will be included to account for potential confounders.

The data analysis will involve several steps. First, the data will be cleaned and prepared for analysis, including handling missing data and ensuring the accuracy and consistency of the variables. Descriptive statistics will be calculated to understand the characteristics of the data and the distributions of the key variables. Logistic regression models will then be used to estimate the impacts of fruit and vegetable consumption and food insecurity on chronic disease outcomes. Sensitivity analyses will be conducted to test the robustness of the results and explore potential biases.

1.8. Thesis Structure

The thesis is structured as follows. The introduction provides an overview of the research topic, outlining the problem statement, research objectives, and significance of the study. The literature review summarizes existing research on the impact of fruit and vegetable consumption and food insecurity on chronic diseases, examining global, national, and Canadian contexts. The

methodology details the data sources, variables, and statistical models, specifically logistic regression analyses, used to explore the relationships between diet, food insecurity, and chronic disease outcomes. The results section presents the findings from these analyses, highlighting key trends and associations. In the Discussion, the results are interpreted in relation to the research objectives, implications are explored, and comparisons are made with existing literature. Finally, the Conclusion and Recommendations summarize the key findings of the thesis and offer policy recommendations to mitigate the burden of chronic diseases through dietary and public health interventions.

Chapter 2 - Literature Review

2.1. Introduction

Chronic diseases such as cardiovascular disease, cancer, diabetes, and high blood pressure are major public health concerns around the world, and they are heavily influenced by dietary habits and socioeconomic factors such as food insecurity. These disorders are strongly linked to dietary habits, with fruit and vegetable intake playing a critical role. Furthermore, food insecurity, which occurs when people lack consistent access to nutritious and sufficient food, might increase the prevalence and severity of these illnesses. This literature review summarizes findings from numerous studies on how fruit and vegetable consumption and food insecurity affect chronic disease prevalence.

Fruits and vegetables, with their high nutrient content, are crucial for health promotion and disease prevention. Numerous studies have demonstrated that these food groups protect against a variety of chronic diseases, mostly through antioxidant properties, fiber content, and vitamin and mineral availability. Food insecurity, defined as a lack of regular access to nutritious and sufficient food, is a significant barrier to nutritious eating and has been associated with poor health outcomes, such as an increased prevalence of chronic diseases. Individuals facing food insecurity frequently turn to cheaper, less nutritious food options, which can lead to vitamin deficiencies and an increased risk of disease. This dietary compromise may increase the likelihood of developing chronic diseases, leading to a vicious cycle of poor health and economic hardship.

Chronic diseases, particularly noncommunicable ones such as type 2 diabetes, cardiovascular disease (CVDs), and cancer, are major public health concerns in Canada. They are the primary causes of death and incur large economic costs (Nshimyumukiza et al., 2018; Solbak

et al., 2017). Diabetes, obesity, heart disease, and high blood pressure are all associated with changes in dietary patterns and physical activity levels, which are influenced by economic, social, and cultural factors (Mukhopadhyay & Thomassin, 2012; Bacon et al., 2019). Over the last century, the shift from infectious to lifestyle-related chronic diseases has placed a significant load on worldwide health systems, including those in Canada.

Recent Canadian studies have sought to understand how adherence to sustainable dietary guidelines impacts the development of chronic diseases. This review aims to synthesize these research findings, focusing on the economic and health implications, the effects of government initiatives, and regional variations in dietary habits across Canada.

2.2. Nutritional Benefits of Fruits and Vegetables

Fruits and vegetables provide important nutrients, dietary fibers, and phytochemicals, all of which provide substantial health advantages. Increased consumption of fruits and vegetables has been associated with a lower incidence of several chronic diseases, including cardiovascular disease and diabetes. Studies have found an inverse link between a fruit and vegetable diet and the prevalence of cardiovascular diseases such as heart disease and stroke. For example, increased consumption of green leafy vegetables was particularly helpful in lowering blood pressure and lowering the risk of cardiovascular events. While the evidence for diabetes is less consistent, there is moderate evidence that eating more fruits and green leafy vegetables may reduce your chance of developing type 2 diabetes. The methods could include regulating postprandial glucose reactions and maintaining a healthy body weight. The link between fruit and vegetable consumption and cancer risk is complex. Some studies suggest a possible preventive impact against specific types of cancer, such as colorectal and breast cancer, although the evidence is not consistent across all cancer types (Boeing et al., 2012).

The role of micronutrients and phytonutrients in processed foods has become a focal point in the study of chronic diseases. The discussion focuses on how antioxidants and other phytochemicals found in plants can have anti-obesogenic effects through various pathways, highlighting the benefits of a diet rich in natural, unprocessed foods. These compounds exert their beneficial impact through various pathways, affecting crucial bodily functions such as appetite regulation, lipid absorption, metabolism, insulin sensitivity, thermogenesis, and the gut microbiota (Tucker, 2020). The understanding of these effects underscores the importance of a

diet rich in natural, unprocessed foods, highlighting the critical role of plant-based nutrients in promoting health and preventing obesity.

Moreover, the global increase in obesity, a major health challenge, is closely linked with subsequent cardiometabolic diseases such as type 2 diabetes and cardiovascular diseases (CVDs) (Tucker, 2020). Tucker (2020) provides an extensive overview of dietary factors related to these cardiometabolic diseases. It emphasizes the protective role of diets high in fruits, vegetables, whole grains, nuts, seeds, and low-fat dairy and low in refined grains, sugary foods, and processed meats against these conditions. Additionally, the chapter points out the protective nature of high-fiber foods like whole grains, legumes, nuts, fruits, and vegetables against obesity, further underscoring the importance of dietary quality in combating major health challenges (Tucker, 2020).

Extensive studies have shed light on the relationship between specific food groups and chronic diseases. These studies identify both protective and risk factors within various food groups in relation to type 2 diabetes and cardiovascular diseases (CVDs). It is established that higher intakes of whole grains, vegetables, fruits, and dairy are associated with a lower risk of these diseases. Conversely, the consumption of processed and red meats, refined grains, and sugar-sweetened beverages (SSBs) is linked to an increased risk. These findings are crucial for understanding the dietary contributors to the prevalence of chronic diseases and are instrumental in shaping public health recommendations. They highlight the importance of dietary choices in managing the risk of type 2 diabetes and CVDs, emphasizing the benefits of natural, unprocessed foods and the risks associated with certain processed foods (Tucker, 2020).

Fruits and vegetables contain a wide range of bioactive compounds, such as vitamins C and E, beta-carotene, flavonoids, and phytochemicals, which have been shown to reduce the risk of cardiovascular diseases, certain cancers, and obesity. For example, a diet rich in fruits and vegetables has been associated with lower blood pressure, reduced inflammation, and improved lipid profiles. Furthermore, dietary fiber found in these foods aids in maintaining healthy digestion and regulating blood sugar and cholesterol levels.

2.3. Relationship Between Fruit and Vegetable Consumption and Chronic Diseases

Dietary habits are among the most significant modifiable risk factors for NCDs. Among various dietary components, the consumption of fruits and vegetables stands out for its potential protective effects against these conditions. Fruits and vegetables are rich in essential vitamins, minerals, fiber, and antioxidants, which play vital roles in the body's metabolic processes and immune functions. These nutrients help reduce inflammation and oxidative stress, two key factors in the development of chronic diseases.

To investigate the association between fruit and vegetable intake and chronic disease risks, studies in this field used a variety of approaches, most notably observational designs such as cross-sectional, cohort, and case-control studies. These studies measured food intakes using self-reported evaluations and validated questionnaires. Statistical studies, such as multivariate regression models, were employed to control for potential confounders such as age, gender, socioeconomic status, and other lifestyle factors (Boeing et al. 2012).

A study done by Azagba and Sharaf in 2012 employed quantile regression to assess the relationship between fruit and vegetable consumption and Body Mass Index (BMI), a key indicator often associated with chronic diseases. The 2004 Canadian Community Health Survey (CCHS), which yielded a nationally representative sample of 11,818 people, served as the data source. This strategy was chosen to account for possibly heterogeneous effects of fruit and vegetable intake across different BMI distributions, hence overcoming the constraints of classic linear regression models that assume uniform effects across the BMI spectrum (Azagba and Sharaf, 2012). The study found that higher fruit and vegetable intake was generally associated with reduced BMI across various quantiles of the BMI distribution, implying a preventive impact against obesity and related chronic illnesses. Azagba and Sharaf (2012) found that people with higher BMI quartiles may benefit more from increased fruit and vegetable consumption. The study’s approach highlights the variable impact of diet across different segments of the population, an aspect that standard regression models might obscure.

A study done on adult obesity in Canada employed a spatial econometric analysis to examine adult obesity patterns across different regions in Canada from 2000/01 to 2009/10. Using data from the Canadian Community Health Surveys, a panel data set was constructed at the health region level. The analysis incorporated spatial panel-data estimation techniques, such

as spatial autoregressive (SAR) and spatial error models (SEM), to account for spatial dependencies and heterogeneities that traditional regression models might miss. This method is critical because it catches the non-random spatial distribution of obesity rates across regions, which could lead to biased estimates if overlooked (Hajizadeh et al., 2015). The spatial econometric analysis found that fruit and vegetable consumption was associated with a lower body mass index (BMI) and lower rates of obesity. This association remained persistent even after accounting for regional heterogeneities and dependencies, indicating these dietary components' strong protective effect against obesity, a major risk factor for a variety of chronic diseases (Hajizadeh et al., 2015).

Recent studies exploring the correlation between sustainable diets and the prevalence of chronic diseases in Canada have yielded significant insights. A key development in this area is the creation and validation of the Healthy Eating Index-Canada 2010 (HEI-C 2010), a tool adapted from its American version to reflect the guidelines of Canada's Food Guide 2007. This index assesses diet quality and its relationship with obesity and chronic disease risk in Canadians. The HEI-C 2010, which demonstrates internal reliability and validity, is a reliable indicator for assessing food quality in Canada.

This index was applied in a study involving 12,805 participants aged 18 and older, data for which was obtained from the Canadian Community Health Survey Cycle 2.2. The methodology included weighted multivariate logistic regression to examine the link between adherence to the HEI-C 2010 and the likelihood of obesity, taking into account socioeconomic factors. The study's validity and reliability were confirmed through principal component analysis and Cronbach's alpha, resulting in a reliability coefficient of 0.78. This coefficient indicates strong internal consistency of the index (Canadian Community Health Survey, 2010).

Further, the HEI-C 2010 revealed a significant inverse relationship between diet quality and obesity. Participants with higher index scores, indicating healthier diets, ate fewer refined grains and empty calories. Instead, they were more likely to include healthy nutrients and foods, including fruits, vegetables, whole grains, and dairy. This food pattern is not only in line with chronic disease prevention standards, but it also mirrors World Health Organization recommended dietary patterns such as the Mediterranean and Nordic diets. These diets are noted for focusing on vegetables, fruits, whole grains, and healthy fats, as well as their effectiveness in reducing chronic diseases (World Health Organization, 2018).

The study also discovered associations between lifestyle, socioeconomic status, and diet quality. According to Jessri, Alena, and Mary (2017), older women, those who were physically active, and non-smokers were more likely to follow healthier eating practices.

2.3.1. Cardiovascular Diseases

Fruits and vegetables play a crucial role in reducing the risk of cardiovascular diseases (CVD). Studies have consistently shown that higher consumption of these foods is associated with a lower risk of heart disease and stroke. Numerous studies highlight the cardiovascular benefits of consuming fruits and vegetables. For example, a systematic review and meta-analysis of 95 studies found that higher intake of fruits and vegetables was associated with a reduced risk of cardiovascular disease and all-cause mortality, with risk reduction observed at intakes of up to 800 grams per day of combined fruits and vegetables (Aune et al., 2017). Specific types of fruits and vegetables, such as apples, pears, citrus fruits, green leafy vegetables, and cruciferous vegetables, have demonstrated particularly strong associations with cardiovascular health, showing inverse relationships with CVD and mortality (Aune et al., 2017).

Several studies have shown the benefits of fruits and vegetables in preventing chronic diseases due to their nutrient, fiber, and phytochemical contents. A comprehensive evaluation found that eating more fruits and vegetables lowers the risk of hypertension, coronary heart disease (CHD), and stroke (Boeing et al., 2012). The evidence for cancer prevention is inconsistent; however, increasing fruit and vegetable intake may reduce overall cancer risk (Boeing et al., 2012).

In a 2013 study, Demydas used structural equation modeling (SEM) to investigate the effects of dietary quality and lifestyle choices on health, with a special emphasis on cardiovascular diseases (CVD). Data were derived from the 2005–2006 US National Health and Nutrition Examination Survey (NHANES), which offered detailed demographic, nutritional, and medical data for a representative sample of the population. This method enabled the modeling of complicated connections between observable and latent variables, including both direct and indirect effects of dietary and lifestyle decisions on health outcomes (T. Demydas, 2013). Fruits and vegetables are high in important nutrients, fiber, and antioxidants, all of which help reduce the risk of chronic diseases. Dietary fibers, for example, can lower blood cholesterol levels and hence lower the risk of cardiovascular disease. Fruits and vegetables include antioxidants that can neutralize free radicals, lowering oxidative stress and inflammation, both of which contribute

to the development of chronic diseases such as heart disease and cancer. Furthermore, fruits and vegetables include potassium, which can help lower blood pressure and protect against heart disease (Demydas, 2013).

Extensive research has demonstrated that eating more fruits and vegetables lowers the risk of chronic diseases, notably cardiovascular disorders. Research from the Nurses' Health Study and the Health Professionals Follow-up Study suggests that eating more fruits and vegetables reduces the risk of cardiovascular events and overall mortality but has no significant impact on cancer incidence (Hung et al., 2004). A large study (Hung et al., 2004) found that increased intake of fruits and vegetables was preventive against cardiovascular illnesses but had no meaningful influence on cancer rates. Among different types of produce, green leafy vegetables had the highest inverse connection with chronic disease risk and cardiovascular events. Each additional serving per day of green leafy vegetables was associated with a modest but statistically significant reduction in the risk of major chronic diseases and cardiovascular conditions (Hung et al., 2004).

The World Health Organization (WHO) also emphasizes the importance of fruit and vegetable consumption in the primary prevention of cardiovascular diseases. According to a WHO review, dietary advice to increase fruit and vegetable intake significantly reduced systolic blood pressure by 3.0 mmHg compared to minimal or no advice, reinforcing the role of a nutrient-rich diet in improving heart health (World Health Organization, 2023).

Dietary patterns rich in whole grains, nuts, and legumes, while low in processed foods, red meat, and sugar-sweetened beverages, such as the Mediterranean and DASH (Dietary Approaches to Stop Hypertension) diets, have been shown to reduce the risk of cardiovascular diseases (Belanger et al., 2023; Estruch et al., 2013).

1. Mediterranean Diet

   The Mediterranean diet, which is rich in minimally processed plant-based foods and monounsaturated fats, particularly from olive oil, has been associated with significant reductions in coronary events and overall mortality. The PREDIMED trial demonstrated a 73% reduction in coronary events and a 70% reduction in total mortality after 27 months of follow-up (Ros, 2019).

2. DASH Diet

   The DASH diet, developed by the National Heart, Lung, and Blood Institute,

emphasizes fruits, vegetables, low-fat dairy, whole grains, poultry, fish, nuts, and seeds. This diet has been proven to lower blood pressure, total cholesterol, and LDL cholesterol, which are major risk factors for cardiovascular disease (Siervo et al., 2023).

3. Plant-Based Diets

    Plant-based diets, which focus on whole grains, legumes, fruits, and vegetables while minimizing processed foods and animal products, have also demonstrated cardioprotective effects. These diets are linked to a reduction in risk factors associated with cardiovascular diseases (Siervo et al., 2023).

2.3.2. Diabetes

Whole grains and dietary fiber have been consistently associated with a lower risk of type 2 diabetes. A meta-analysis of 11 prospective cohort studies, including 463,282 participants and 37,249 type 2 diabetes cases, found that higher whole grain intake was associated with a 21% reduced risk of type 2 diabetes (RR: 0.79, 95% CI: 0.73-0.85) (Zhu et al., 2022). The study also revealed that consuming an additional 50 grams of whole grains per day was associated with a 23% reduced risk of type 2 diabetes (Zhu et al., 2022). Similarly, a systematic review and meta-analysis published in *PLOS Medicine* found that increasing dietary fiber intake by 15 grams per day or reaching 35 grams per day can improve glycemic control in individuals with prediabetes, type 1, or type 2 diabetes (McRae, 2020).

High intake of processed foods and sugary beverages is linked to an increased risk of type 2 diabetes. A review of studies on sugar-sweetened beverages (SSBs) and type 2 diabetes risk found that current SSB consumption levels are associated with an increased incidence of type 2 diabetes (Malik et al., 2021). The review also noted that a 10% reduction in SSB consumption would decrease diabetes incidence over a 10-year period in adults aged 35 and older (Malik et al., 2021). Additionally, a mini-review on ultra-processed food (UPF) consumption concluded that high consumption of UPF, defined as more than 10% of the diet, could increase the risk of developing type 2 diabetes in adults (Pagliai et al., 2022). The review suggests that replacing SSBs with water, unsweetened tea, or coffee is a more effective strategy for lowering diabetes risk than substituting with diet or zero-calorie sweetened beverages (Malik et al., 2021).

These findings underscore the importance of dietary choices in diabetes prevention and management. Increasing consumption of whole grains and fiber while reducing intake of processed foods and sugary beverages can significantly impact the risk of developing type 2 diabetes.

2.3.3. Cancer

Fruits and vegetables, particularly those rich in antioxidants and phytochemicals, have been associated with a reduced risk of various cancers. A comprehensive review of epidemiological studies found that high intake of fruits and vegetables was linked to a reduced risk of several cancers, including colorectal cancer. Cruciferous vegetables, such as broccoli and kale, have been specifically associated with a lower risk of colorectal cancer. These vegetables contain glucosinolates, which are converted into isothiocyanates and indoles in the body—compounds recognized for their anti-cancer properties. A meta-analysis of prospective studies revealed that high intake of cruciferous vegetables was associated with an 18% reduction in colorectal cancer risk (RR = 0.82; 95% CI: 0.75-0.90) (Wu et al., 2015).

On the other hand, high consumption of red and processed meats has been linked to an increased risk of colorectal and other cancers. Substituting these with plant-based proteins can help reduce cancer risk (PubMed). The World Health Organization's International Agency for Research on Cancer (IARC) has classified processed meat as Group 1 (carcinogenic to humans) and red meat as Group 2A (probably carcinogenic to humans) (World Health Organization, 2015).

The relationship between diet and chronic diseases has been extensively studied, and existing research provides strong evidence that dietary patterns significantly influence the risk of developing chronic diseases. Conversely, food insecurity, defined as the lack of consistent access to sufficient and nutritious food, exacerbates the risk and severity of NCDs. Food-insecure individuals often resort to cheaper, energy-dense, and nutrient-poor food options, leading to poor dietary quality and increased health risks. This cyclical relationship between food insecurity and chronic diseases underscores the importance of ensuring access to nutritious foods as a public health priority.

2.4. Impact of Food Insecurity on Dietary Choices and Health

2.4.1. Definition and Prevalence of Food Insecurity

Food insecurity, or insufficient access to adequate food, might increase the risk of chronic diseases. According to studies, food-insecure populations have lower dietary quality, which leads to an increase in obesity and related chronic diseases such as type 2 diabetes and hypertension. This connection stresses the relevance of socioeconomic status to illness frequency, challenging efforts to improve public health only through dietary standards.

Data from the Canadian Community Health Survey, conducted by Statistics Canada, reveals a high prevalence of chronic diseases such as arthritis, high blood pressure, and asthma among residents of northern Canada, including both Aboriginal and non-Aboriginal populations. Additionally, these regions show notably high rates of obesity and smoking, factors that contribute to an increased risk of cardiovascular diseases and certain forms of cancer (Lix et al., 2010). The survey provides comprehensive information on chronic health conditions, risk factors, and lifestyle habits in these northern communities. It underscores the significant public health concern posed by non-communicable diseases in Canada, where dietary patterns play a crucial role.

Furthermore, a study examining the macroeconomic impacts of adopting a healthy diet in Canada, using an input-output framework, indicates a notable shift in the prevalence of conditions like diabetes and obesity. This shift is attributed to dietary consumption patterns and physical inactivity. The study highlights the significant economic and health burdens of chronic diseases in Canada, drawing attention to the escalating costs and increased morbidity and mortality associated with these noncommunicable diseases (Mukhopadhyay & Thomassin, 2012).

Northern Canada faces unique health challenges, as highlighted by data from the Canadian Community Health Survey. This survey reveals significant ethnic and regional variations in the prevalence of chronic diseases and associated risk factors between Aboriginal and non-Aboriginal populations in these areas (Lix et al., 2010). A cross-sectional analysis for different time periods indicates an increasing trend in conditions such as heart disease, arthritis, and asthma, alongside rising risk factors including overweight, obesity, and smoking. These trends suggest an urgent need for targeted health policy interventions and further research to understand the determinants of health in these communities.

Particularly noteworthy is the higher prevalence of chronic diseases and risk factors such as smoking and infrequent physical activity among Aboriginal populations in northern Canada, compared to other Canadian regions (Lix et al., 2010). This situation underscores the importance of implementing culturally sensitive health policies and community-based primary prevention interventions. Such measures are essential for effectively addressing the unique health challenges faced by these communities (Lix et al., 2010).

Over the past century, there has been a global shift in disease prevalence from infectious to chronic conditions, significantly burdening health systems worldwide, including Canada's. Chronic diseases such as type 2 diabetes, cardiovascular diseases (CVDs), and cancer have become leading causes of death, with a profound economic impact (Nshimyumukiza et al., 2018; Solbak et al., 2017). In 2015, unhealthy dietary habits, specifically low vegetable and fruit intakes combined with high consumption of sugar-sweetened beverages, were responsible for 37% of all deaths globally (Nshimyumukiza et al., 2018). Furthermore, the increase in chronic conditions like type 2 diabetes is closely linked with rising obesity rates, a situation exacerbated by the dietary shift from basic to processed foods, which often results in the loss of specific nutrients (Tucker, 2020).

Despite the recent increase in obesity and diabetes rates, there has been a notable decline in mortality from cardiovascular diseases. This improvement is largely attributed to advancements in primary and secondary prevention methods, including dietary modifications. Diet continues to be a significant modifiable risk factor for cardiovascular diseases (Tucker, 2020).

2.4.2. Food Insecurity in Canada

Food insecurity remains a pressing issue in Canada, with a significant portion of the population affected. In 2023, 8.7 million Canadians, including 2.1 million children, were living in food-insecure households, representing 22.9% of the population across the ten provinces (Burton, 2024). This figure reflects a worrying increase from 2022, during which nearly nine million Canadians reported some level of food insecurity, with the percentage of severely food-insecure households rising from 4.0% in 2022 to 6.0% in 2023 (Canadian Income Survey [CIS], 2018–2022). Food insecurity refers to inadequate or insecure access to food due to financial constraints and can be categorized as marginal, moderate, or severe based on the extent of deprivation.

The prevalence of food insecurity varies across provinces, with Quebec reporting the lowest rate at 14%, while Newfoundland and Labrador (23%), New Brunswick (22%), and Alberta (22%) had the highest rates (Statistics Canada). Demographic factors also play a significant role. Families with a female major income earner were more likely to experience food insecurity (21%) compared to those with a male major income earner (16%). This disparity is particularly pronounced among female lone-parent families, where the food insecurity rate reaches 41% (Statistics Canada). Additionally, racial and ethnic disparities persist, as families with a racialized major income earner (23%) reported higher food insecurity rates than those with a non-racialized, non-Indigenous earner (16%). Black Canadians were particularly vulnerable, with 38% reporting food insecurity (Statistics Canada).Indigenous populations are

also disproportionately affected. Families with an Indigenous major income earner living off-reserve in the provinces reported food insecurity at a rate of 34%, nearly double that of non-Indigenous families (18%) (Statistics Canada). Furthermore, there is a strong correlation between food insecurity and poverty, with over one-third (35%) of families living below the poverty line experiencing food insecurity, compared to 16% of families living above the poverty line (Statistics Canada).

The persistently high rates of food insecurity in Canada underscore the urgent need for effective, evidence-based policy interventions by federal and provincial governments to address this issue and its associated chronic health challenges.

2.4.3. Food Insecurity and Poor Dietary Quality

Food insecurity frequently leads to excessive eating of inexpensive, energy-dense foods with low nutritional value. This dietary pattern is linked to an increased risk of obesity and other chronic diseases, such as cardiovascular disease and diabetes. In terms of mental health, prolonged stress caused by food scarcity can result in poor dietary choices, raising the risk of chronic disease. As a result, addressing food poverty requires a multifaceted approach that incorporates economic policies, social support networks, and community-based activities to ensure access to nutritious meals (Boeing et al. 2012).

The study by Demydas emphasized the indirect impacts of socioeconomic factors such as education and income on food behaviors. Lower income and education levels are frequently connected with higher levels of food insecurity, resulting in an increased intake of low-cost, nutrient-poor foods that are high in calories but deficient in vital nutrients. This pattern of eating

contributes to the prevalence of obesity, diabetes, and other diet-related chronic conditions (Demydas, 2013).

The study done by Dudek (2019) utilized data from the European Union Statistics on Income and Living Conditions (EU-SILC) survey from 2017, applying logistic regression models to identify socio-economic and demographic predictors of food insecurity. In order to gauge the frequency of food insecurity, the survey asked households if they could afford to eat a dinner consisting of meat, chicken, fish, or a vegetarian substitute every other day. The logistic regression analysis of the study revealed that food insecurity is highly associated with a variety of socioeconomic characteristics, including income, household composition, and urbanization. Lower-income households, those with single parents, and those living in urban areas were more likely to experience food insecurity. The intricate relationship between socioeconomic position, food insecurity, and health is highlighted by the fact that these characteristics are linked to poorer health outcomes and a higher incidence of chronic diseases (Dudek, 2019).

McLeod and Veall conducted a longitudinal study in 2006 using data from the Canadian National Population Health Survey, which spans the years 1994/95 to 2010/11. This survey asked about food insecurity and provided extensive health assessments over numerous cycles. The study employed regression analysis to investigate the long-term associations between food insecurity, fruit and vegetable consumption, and health outcomes. McLeod and Veall (2006) used questions to assess food insecurity, including the ability to afford healthy meals and the experience of running out without the resources to buy more (McLeod & Veall, 2006). The study found that people who are food insecure had poorer health outcomes than those who are food secure. Reduced nutritional intake and increased psychological stress have been identified as mechanisms that may cause or exacerbate chronic disorders such as diabetes, hypertension, and cardiovascular disease.

2.4.4. Link to Chronic Diseases

Food insecurity can contribute to chronic disease through a variety of biological processes. Poor dietary quality and a lack of frequent access to nutritional meals can cause vitamin and nutrient deficiencies, compromising immunity and increasing disease susceptibility. Chronic low intake of fruits and vegetables has been associated with an increased risk of heart disease, obesity, and diabetes. Food insecurity-induced physiological stress can also result in chronic inflammation, which is a known risk factor for many chronic diseases.

Consuming fruits and vegetables is recognized to have numerous health benefits, including the prevention of chronic diseases. These foods are high in dietary fiber, vitamins, minerals, and antioxidants, all of which help to reduce inflammation and oxidative stress, two critical factors in the development of chronic diseases, including heart disease and cancer. The research examines how higher consumption of fruits and vegetables correlates with improved health markers and reduced disease incidence, demonstrating their protective effects against chronic illnesses (McLeod & Veall, 2006).

Another study conducted by Smith in 2021 used a multicountry panel data analysis spanning 31 sub-Saharan countries from 2001 to 2018. The data came from the United Nations Development Programme, the Food and Agriculture Organization, and the World Bank. This large dataset includes characteristics of dietary energy supply and undernourishment prevalence. Smith (2021) analyzed the complex relationship between food security and health outcomes using Driscoll-Kraay standard errors, the generalized method of moments, fixed effects models, and Granger causality tests (Smith, 2021). The study demonstrates that food insecurity has a clear detrimental impact on health, indicating that an increase in undernourishment prevalence is associated with higher infant mortality and reduced life expectancy. According to Smith (2021), this implies that having insufficient access to nutrient-dense food makes people more vulnerable to chronic illnesses like malnutrition. Food insecurity causes low dietary intakes, which lack the nutrients required for disease prevention and overall health maintenance, increasing the prevalence and severity of chronic illnesses.

Food instability frequently causes nutritional deficiencies, which impede vital cellular and systemic functioning. For example, a lack of fruits and vegetables can result in vitamin and mineral deficiencies that impair immune function and metabolism, increasing vulnerability to chronic diseases. The study found a link between inadequate dietary energy supply and negative health outcomes, highlighting the importance of the continuous availability of healthy meals in combating chronic diseases (Smith, 2021).

The study illustrates the strong link between diet, food security, and health. Addressing food insecurity thus not only helps to achieve the Sustainable Development Goals, but it also constitutes an important public health strategy for reducing chronic disease burdens in vulnerable groups. Continued efforts to improve food security and ensure appropriate fruit and vegetable consumption could result in major health gains in Sub-Saharan Africa and beyond. Future studies

should focus on specific dietary components, such as fruits and vegetables, in relation to chronic disease prevention in food-insecure people.

Gundersen and Ziliak (2015) examined the influence of food insecurity on health outcomes across various groups in the United States. The key data sources were the Current Population Survey's Food Security Supplement (CPS-FSS) and other nationally representative datasets, which enabled the authors to investigate a broad socioeconomic spectrum and capture a diverse range of food insecurity experiences.

Gundersen and Ziliak employed quantitative methods to link degrees of food insecurity to various health consequences. Food insecurity was assessed using the CPS-FSS, which consists of a series of questions about the availability and sufficiency of food in households. Based on their responses, this measure categorizes households into various levels of food security, ranging from high to very low. The study used multivariate regression models to determine the impact of food insecurity while accounting for potential confounders such as income, employment status, and other socio-demographic characteristics.

The study highlighted that food insecurity is consistently associated with adverse health outcomes across all age groups. For children, food insecurity increases the risk of conditions such as anemia, cognitive problems, and overall poor health. Among adults, correlations were found with chronic conditions such as diabetes and hypertension. These health impacts are attributed to both the direct effects of inadequate nutrition and the psychological stress associated with food insecurity (Hosseini et al., 2018).

The study emphasizes food insecurity as a major cause of health disparities, with serious consequences for public health strategies. It implies that measures aimed at improving food security, such as the Supplemental Nutrition Assistance Program (SNAP), play a substantial role in minimizing these inequities by providing improved access to nutritious food, particularly fruits and vegetables (Hosseini et al., 2018).

This study shows a clear and consistent relationship between food insecurity and negative health outcomes, which is mediated by inadequate nutritional intake, especially insufficient consumption of fruits and vegetables. Gundersen and Ziliak (2015) research provides a solid empirical foundation for policy recommendations aimed at reducing food insecurity in order to battle chronic diseases. Further study should be conducted to investigate the causal links and

long-term effects of enhanced nutritional access through public health interventions (Hosseini et al., 2018).

2.4.5. Regional and Socioeconomic Disparities

Chronic disease prevalence and food insecurity are not evenly distributed across Canada. Significant regional and socioeconomic disparities exist, with Indigenous communities, low-income populations, and residents of remote areas bearing a disproportionate burden of both chronic diseases and food insecurity.

This study focuses primarily on the economic and health consequences of dietary choices, including the implications for obesity and chronic diseases. In addition, it looks at the unique nutritional challenges that northern Canadians, especially Aboriginal populations, experience and the striking change in the prevalence of chronic diseases over the past century from infectious to lifestyle-related diseases.

Indigenous Communities

Indigenous populations in Canada, comprising 4.9% of the country's population, face disproportionately higher rates of chronic diseases compared to their non-Indigenous counterparts. For instance, cardiovascular diseases affect 7.1% of Indigenous adults, compared to 5% of non-Indigenous Canadians. This disparity highlights the significant health challenges Indigenous communities endure (Elamoshy, 2018). Moreover, the lifetime risk of diabetes is notably higher among Indigenous peoples, with a rate of 57%, compared to 44.5% in the non-Indigenous European population (Elamoshy, 2018).

In addition to these specific chronic conditions, Indigenous populations are more likely to suffer from multiple chronic conditions. For example, 15% of First Nations people living off-reserve and 16% of Métis reported being diagnosed with two chronic conditions, compared to 12% of non-Indigenous individuals. Furthermore, 14% of both First Nations and Métis reported having three or more chronic conditions, compared to only 8% of non-Indigenous Canadians (Statistics Canada, 2022).

These health disparities stem from historical and systemic inequities that have persisted for generations. The root of these disparities can be traced back to early colonization, which aimed to dismantle the sociocultural, economic, educational, and health foundations of Indigenous communities in Canada (Elamoshy, 2018).

Low-Income Populations

Food insecurity remains a significant issue among low-income populations in Canada, with those living below the poverty line being particularly vulnerable. Recent data shows that 11% of families had incomes below the poverty line, and these families experienced food insecurity at nearly twice the average rate, with 35% of them affected compared to 18% of the overall population. Notably, many families experiencing food insecurity had incomes above the poverty line, highlighting that food insecurity is not limited to only the poorest families (Statistics Canada, 2023).

The problem has worsened in recent years, with household food insecurity in Canada's ten provinces reaching an all-time high. Data from the Canadian Income Survey revealed that in 2022, 17.8% of households faced inadequate or insecure access to food due to financial constraints, up from 15.9% in 2021 (The Conversation, 2023).

The health implications of food insecurity are severe, impacting not just nutrition but a wide range of physical and mental health outcomes. Food insecurity has been linked to diet-related diseases and poor nutrition, as well as other adverse health conditions, including mental health issues and premature death (The Conversation, 2023).

Remote and Northern Communities

Food insecurity in remote and northern communities, particularly in Nunavut, remains a persistent and severe issue. In 2017/2018, 49.4% of households in Nunavut experienced food insecurity, with 25.8% of households classified as moderately food insecure and 23.7% as severely food insecure. Among households with children, 62.4% reported food insecurity among adults, and 42.7% among children, making Nunavut the region with the highest rates of food insecurity in Canada (Statistics Canada). Some estimates suggest that nearly 70% of Nunavut’s population faces food insecurity, highlighting the scale of the crisis (Canada Without Poverty).

In 2023, Nova Scotia reported the highest percentage of individuals living in food-insecure households at 28.9%, followed by P.E.I. at 28.6% and Saskatchewan at 28.0% (Canadian Income Survey [CIS], 2018–2022). Quebec, on the other hand, had the lowest prevalence of household food insecurity at 13.8% in 2022 (Canadian Income Survey [CIS], 2018–2022). Food insecurity is also particularly high in the northern territories, with 46.1% of people in Nunavut, 22.2% in the Northwest Territories, and 12.8% in Yukon living in food-insecure households in 2022 (Canadian Income Survey [CIS], 2018–2022).

One of the main factors driving food insecurity in Nunavut is the exorbitant cost of food. In 2016, grocery costs in Nunavut were reported to be up to three times higher than in the rest of Canada, further limiting access to nutritious food (Canada Without Poverty, 2021). Additionally, the impacts of colonialism continue to affect Inuit food systems, with reduced participation in traditional food harvesting and a diminished transfer of ecological knowledge, particularly among younger generations, further exacerbating food insecurity (Power, 2019).

Indigenous communities across Canada are disproportionately affected by food insecurity. In 2022, 33.4% of off-reserve Indigenous Peoples in the ten provinces lived in food-insecure households (Canadian Income Survey [CIS], 2018–2022). Families with an Indigenous major income earner were almost twice as likely to report food insecurity (34%) compared to families with a non-Indigenous major income earner (18%) (Statistics Canada, 2023).

Addressing food insecurity in Nunavut and other remote communities requires targeted interventions. This issue must be a national priority, and continued monitoring is essential to ensure progress (The Government of Canada, 2024).

Chronic diseases disproportionately impact low- and middle-income countries (LMICs). Each year, 17 million people die from non-communicable diseases (NCDs) before the age of 70, with 86% of these premature deaths occurring in LMICs (Allen et al., 2017). These countries often face a double burden, contending with both infectious diseases and a sharp rise in NCDs. This contrasts with high-income nations like Canada, where lifestyle-related conditions are the primary health concern, and public health systems are better equipped to manage and prevent such diseases.

In low-income countries, the burden of chronic diseases is exacerbated by limited access to healthcare, nutritious food, and preventive measures. While Canada benefits from widespread availability of fruits and vegetables and public health initiatives promoting healthy diets, populations in regions such as Sub-Saharan Africa and South Asia struggle with barriers to accessing basic nutrition. This lack of access increases their vulnerability to both infectious diseases and NCDs.

Progress toward achieving NCD-related targets has been slow and has been further disrupted by the COVID-19 pandemic. Currently, only a few countries are on track to meet the Sustainable Development Goal (SDG) of reducing premature mortality from NCDs by one-third

by 2030 (Allen et al., 2017). Addressing these global health disparities will require international cooperation to improve healthcare access, reduce food insecurity, and support sustainable development initiatives in the most affected regions.

Chronic diseases are highly prevalent in Canada, with 44% of adults aged 20 and older living with at least one of the 10 most common chronic conditions (Government of Canada, "Prevalence of Chronic Diseases"). Among these conditions, hypertension affects 25% of the population, osteoarthritis impacts 14%, mood and anxiety disorders are reported by 13%, while 11% of adults are living with diabetes and asthma. Additionally, 10% of adults are affected by chronic obstructive pulmonary disease (COPD) (Government of Canada, 2019).

Mortality rates from chronic diseases are also significant. Cardiovascular disease (CVD) remains the second leading cause of death in Canada, with a crude mortality rate of 196 per 100,000 people, accounting for 27% of all deaths. Cancer, however, remains the leading cause of death, with a crude mortality rate of 215 per 100,000 people, representing 29% of all deaths in 2015 (Public Health Agency of Canada). While data specifically comparing Canada's non-communicable disease (NCD) mortality to other high-income countries is limited, Canada's NCD-related mortality rate aligns with that of other developed nations, where NCDs account for the majority of deaths.

In addition to chronic disease prevalence, food insecurity in Canada remains a serious issue. In 2023, 8.7 million Canadians, including 2.1 million children, were living in food-insecure households, as reported by Statistics Canada's Canadian Income Survey (Canadian Income Survey [CIS], 2018–2022). Food insecurity is a key contributor to chronic health conditions, as inadequate access to nutritious food exacerbates the risk of developing diet-related diseases.

2.4.6. International Efforts to Combat Food Insecurity and NCDs

Climate change is intensifying food insecurity, particularly in vulnerable countries. Rising temperatures, erratic weather patterns, and more frequent extreme events like droughts and floods are disrupting agricultural production and threatening global food supplies. According to the Intergovernmental Panel on Climate Change (IPCC) Special Report on Climate Change and Land, climate change is already affecting food security through increasing temperatures, shifting precipitation patterns, and more frequent extreme events. The report highlights that

yields of key crops, such as maize and wheat, have been negatively impacted in many lower-latitude regions due to these changes (IPCC, 2019).

The World Bank reports that approximately 80% of the global population most at risk from crop failures and hunger due to climate change is located in Sub-Saharan Africa, South Asia, and Southeast Asia. These regions are highly vulnerable due to their dependence on agriculture and widespread poverty among farming communities (World Bank, 2022).

In addition to affecting staple crops, climate change is reducing the availability of nutritious foods such as fruits and vegetables, pushing many populations toward cheaper, less healthy food options. This shift increases the risk of chronic diseases. The IPCC report also notes that climate change affects not only food availability but also access, utilization, and the stability of food systems over time, leading to potential shifts in dietary patterns (IPCC, 2019).

While Canada is less directly impacted by food scarcity due to its strong agricultural system, it faces indirect consequences from global food system disruptions. A study published in the *International Journal of Environmental Research and Public Health* points out that climate change is affecting food security in Canada's northern and Indigenous communities, where traditional food sources and storage practices are being threatened. The country's northern regions are experiencing compromised access to traditional foods, further worsening food insecurity in Indigenous communities (Robidoux et al., 2019).

To address the global burden of non-communicable diseases (NCDs) and food insecurity, several research and implementation gaps must be bridged. There is a need for implementation research to accelerate the scaling of cost-effective NCD interventions, particularly in resource-limited settings (Allen et al., 2017). A renewed research agenda should focus on the social and commercial determinants of health, the prevention of shared risk factors, and effective management within broader health systems. Additionally, implementing integrated strategies at the primary healthcare level is crucial to enhance NCD prevention and management (Allen et al., 2017). Improved health information systems, especially in sub-Saharan Africa, are necessary to better understand the epidemiology of NCDs and inform effective prevention and control interventions (The Lancet Global Health, 2019).

Various international initiatives are focused on improving food security and promoting healthier diets as part of the effort to curb chronic diseases. Some key efforts include:

1. World Health Organization’s Global Action Plan for the Prevention and Control of NCDs:

   This plan aims to reduce premature mortality from NCDs by 25% by 2025. It encourages countries to implement policies promoting healthier diets, reduce tobacco and alcohol use, and increase physical activity. A critical aspect of this plan is improving food security by ensuring that nutritious foods, including fruits and vegetables, are more accessible and affordable. (World Health Organization, 2013).

2. United Nations Sustainable Development Goals (SDGs):

   The SDG 2: Zero Hunger aims to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture by 2030. SDG 3 also focuses on ensuring healthy lives and promoting well-being for all ages, with an emphasis on reducing NCDs. These goals call for global cooperation to address the root causes of food insecurity and malnutrition, particularly in low-income countries. (United Nations, 2024).

3. Scaling Up Nutrition (SUN) Movement:

   This is a global initiative uniting governments, civil society, and the private sector to combat malnutrition in all its forms. It focuses on improving access to nutritious foods, especially for vulnerable populations like children, and ensuring that food systems promote health and sustainability. (United Nations, 2024).

Several international initiatives are actively addressing the global challenges of food insecurity and chronic diseases. One of the key efforts is the Global Action Plan for the Prevention and Control of NCDs (NCD-GAP), initially endorsed by the World Health Assembly for the period 2013-2020 and now extended to 2030. This plan focuses on reducing the global burden of non-communicable diseases (NCDs) (Government of Canada, 2019). Another significant framework is the United Nations Sustainable Development Goals (SDGs), which include specific targets aimed at tackling both food security and NCDs. SDG 2 aims to "end hunger, achieve food security and improved nutrition, and promote sustainable agriculture" (Canadian Income Survey [CIS], 2018–2022). Similarly, SDG 3 emphasizes ensuring healthy lives and promoting well-being for all at all ages, including addressing NCDs (Government of Canada, 2023).

In addition, the Scaling-Up Nutrition (SUN) Movement has been pivotal in linking nutrition to various other sectors such as agriculture, clean water, sanitation, education,

employment, and social protection. This integrated approach not only supports better nutrition but also builds resilience and improves overall public health outcomes (Canadian Income Survey [CIS], 2018–2022).

2.5. Social Determinants of Health

Social determinants of health, such as income, education, and access to healthcare, significantly influence the prevalence of NCDs. In Canada, disparities in these determinants contribute to unequal health outcomes across different population groups. Lower-income individuals and those with less education are more likely to experience food insecurity, which in turn increases their vulnerability to NCDs. Addressing these social determinants is crucial for reducing health disparities and improving overall population health.

Income levels play a critical role in determining access to nutritious food. Individuals with higher incomes are more likely to afford a diet rich in fruits and vegetables, while those with lower incomes may rely on cheaper, less nutritious food options. Educational attainment is also linked to dietary habits, as individuals with higher education levels tend to have better knowledge of healthy eating practices and are more likely to follow dietary guidelines. Access to healthcare services further influences the prevention of NCDs, as regular medical check-ups and preventive care can help detect and address health issues early.

The dynamic relationship between nutrient-dense food intake and food accessibility presents a challenging environment for public health professionals and policymakers seeking to reduce the prevalence of chronic diseases. Through a comprehensive analysis of the range of studies pertaining to the nutritional benefits of fruits and vegetables and the wider socio-economic consequences of food insecurity, the purpose of this review is to summarize significant findings, identify gaps in the existing body of literature, and suggest avenues for further research and intervention. This comprehensive approach will not only improve our understanding of how diet influences chronic disease but will also inform effective public health initiatives for diverse populations.

Addressing food insecurity and improving access to nutritious foods are essential components of public health strategies aimed at reducing the burden of NCDs. By ensuring that all individuals have the resources and knowledge to maintain a healthy diet, policymakers can help mitigate the impact of these diseases and promote better health outcomes.

2.6. Economic Burden of Poor Diets and Food Insecurity

The study by Loewen et al. in 2019 sheds light on the significant economic implications of dietary choices, specifically in the context of chronic disease prevalence in Canada due to noncompliance with Canadian food recommendations. Utilizing data from the 2015 Canadian Community Health Survey, which included 24-hour dietary recalls from 19,797 participants, this research utilized the Population Attributable Fractions approach and economic modeling to assess the impact. The findings showed that in 2018, the economic burden of noncompliance with food recommendations reached an estimated CAD$15.8 billion. This figure encompasses both direct healthcare costs and indirect costs, such as lost productivity, highlighting the profound financial consequences of dietary choices on public health (Canadian Community Health Survey, 2018). Notably, the study revealed that the indirect costs associated with underconsumption of healthy foods, like whole grains and nuts, were significantly higher than those related to overconsumption of harmful foods. This emphasizes the need for a dietary shift towards more healthful options in the Canadian diet.

Additionally, the research highlighted a concerning gap in adherence to healthful food recommendations, particularly in the consumption of whole grains, nuts, seeds, and vegetables. When you consider the economic impact associated with different diseases, this nutritional disparity becomes much more substantial. Diabetes and cardiovascular disease, which are heavily influenced by dietary choices, accounted for a greater economic burden than chronic kidney disease and cancer, particularly among younger demographics under the age of 54 (Canadian Community Health Survey, 2018). The study also found that Canadians adhered to fewer recommendations for healthy foods than for harmful foods, such as processed meats, indicating a compelling need for a dietary adjustment (Loewen et al., 2019).

In conclusion, the literature reviewed establishes a clear and compelling link between diet quality, as assessed by the HEI-C 2010, and the prevalence of chronic diseases in Canada. The significant economic burden associated with poor dietary habits underscores the urgency of effective public health strategies to encourage healthier eating patterns. These findings advocate for the adoption of dietary patterns akin to the Mediterranean and Nordic diets and call for policy interventions to improve adherence to healthy eating patterns within the Canadian context.

Nshimyumukiza et al. (2018) conducted an in-depth study to assess the economic burden of chronic diseases in Canada, particularly focusing on the impact of diet quality. Employing the

Healthy Eating Index-Canada-2010 (HEI-C-2010) for evaluating dietary quality, the study used a prevalence-based cost-of-illness approach, with data sourced from the Canadian Community Health Surveys (CCHS) and various meta-analyses. The findings revealed a noteworthy improvement in the diet quality of Canadians between 2004 and 2015, which corresponded to a reduction in the economic burden by $133 million. However, despite this improvement, the study highlighted that the majority of the Canadian population continues to consume diets of poor quality. This underscores the ongoing need for public health interventions aimed at enhancing diet quality across Canada (Nshimyumukiza et al., 2018).

Solbak et al. (2017) conducted a study using the Healthy Eating Index-2005 Canada (HEI-2005-Canada) to explore the relationship between diet quality and the risk of chronic diseases. Their research involved analyzing the dietary patterns of participants in Alberta's Tomorrow Project (ATP), with a focus on the development of chronic diseases. Utilizing food frequency questionnaires completed by 25,169 participants, the study applied Cox proportional hazards models to estimate hazard ratios for chronic disease incidence. The results indicated that better diet quality was associated with a lower risk of cancer in men and a reduced risk of chronic diseases in both sexes. This finding highlights the critical role of dietary quality in preventing chronic diseases (Solbak et al., 2017).

In a broader context, not meeting Canadian food recommendations accounts for a significant economic burden, estimated at CAD $13.8 billion per year. This includes direct healthcare costs of CAD $5.1 billion and indirect costs, such as lost productivity, amounting to CAD $8.7 billion (Lieffers et al., 2018). Furthermore, dietary habits play a role in the global increase in obesity, which is closely linked to cardiometabolic disorders such as type 2 diabetes and cardiovascular disease (CVD) (Tucker, 2020). Tucker (2020) provides a detailed assessment of dietary components related to cardiometabolic disorders. The chapter highlights that diets high in fruits, vegetables, whole grains, nuts, seeds, and low-fat dairy, as well as low in refined grains, sugary foods, and processed meats, can help prevent these illnesses. It also emphasizes the complexities of food effects on the body as well as the importance of conducting diverse studies across multiple populations in order to establish reliable links between diet and health.

The World Health Organization (WHO) has identified poor eating as a major risk factor for mortality and disability in Canada. Such diets have a significant economic impact, with an estimated annual cost of $13.8 billion. This expense is mostly driven by the consumption of

processed meals high in calories, salt, sugar, and saturated fat. The majority of Canadians consume more than the recommended amount of these nutrients, contributing considerably to the rising prevalence of chronic disorders (Bacon et al., 2019).

Chronic diseases not only affect individual health but also impose a considerable economic burden on Canada's healthcare system, including both direct healthcare costs and indirect costs such as lost productivity due to disability and premature death. In Ontario alone, the total annual economic burden of chronic disease risk factors is substantial. According to a study published in the journal *Health Promotion and Chronic Disease Prevention in Canada*, tobacco smoking accounts for $7.0 billion, alcohol consumption for $4.5 billion, physical inactivity for $2.6 billion, and unhealthy eating for $5.6 billion, with $1.8 billion attributed specifically to inadequate vegetable and fruit consumption (Public Health Ontario, 2019).

A different study found that not meeting Canadian food recommendations costs CAD$13.8 billion annually, including CAD$5.1 billion in direct healthcare costs and CAD$8.7 billion in indirect costs. This estimate was later updated in 2018 to CAD$15.8 billion, with CAD$5.9 billion in direct costs and CAD$9.9 billion in indirect costs (Lieffers et al., 2018). The economic impact of chronic diseases extends beyond direct healthcare spending, contributing to increased absenteeism, long-term disability, and premature mortality, particularly among working-age Canadians (Elmslie, 2016).

As the population ages and the prevalence of chronic diseases continues to rise, this economic burden is expected to increase further (Elmslie, 2016). Addressing key risk factors such as poor diet, physical inactivity, and tobacco use is essential to reducing the prevalence of chronic diseases and mitigating their economic impact (Elmslie, 2016).

2.7. Research Gaps

The reviewed studies provide valuable insights into the relationships between diet, food insecurity, and chronic disease prevalence, but they also highlight significant gaps that warrant further exploration. Nyanchoka et al. (2022) investigated the association between fruit and vegetable consumption and chronic disease risk among university students in Kenya, finding significant links between low fruit and vegetable intake and chronic disease risk factors using binary logistic regression. However, the study’s focus on a young, geographically specific population limits its applicability to broader demographic groups or the influence of national

dietary policies. Similarly, Martínez-González et al. (2011) examined fruits and vegetable consumption trends and chronic disease risk among Spanish university graduates. While they observed an inverse association with cardiovascular disease, findings for diabetes and cancer were inconsistent, and the study's focus on a highly health-conscious cohort reduces its generalizability to more diverse populations.

The Canadian Community Health Survey (2010) utilized the Healthy Eating Index-Canada 2010 (HEI-C 2010) to assess diet quality and its association with obesity risk through weighted multivariate logistic regression. While it confirmed the HEI-C's reliability and validity, the study's primary focus was on obesity and diet quality rather than chronic disease outcomes or the evolution of dietary patterns over time. Dudek (2019) used logistic regression to explore socioeconomic and demographic predictors of food insecurity in the EU, highlighting associations between food insecurity, income, household composition, and urbanization. However, this study emphasized the broader impacts of food insecurity on health without investigating the specific dietary components contributing to chronic disease risk.

My research aims to address these gaps by exploring the relationship between fruit and vegetable consumption and chronic diseases in Canada while accounting for demographic, socioeconomic, and regional factors. Utilizing data from the Canadian Community Health Survey (CCHS) spanning 16 years (2004–2020), I will assess the impact of fruit and vegetable consumption on chronic disease outcomes, focusing on the effectiveness of dietary interventions and the role of food insecurity. By employing univariate and multivariate logistic regression models, my study will provide a nuanced understanding of these relationships. Univariate models will establish baseline associations between fruit and vegetable consumption and specific chronic diseases, while multivariate models will adjust for potential confounders such as age, income, and education, enabling a deeper interpretation of these interactions. Provincial analyses will further contextualize these findings, offering insight into regional differences and local factors influencing dietary behaviors and health outcomes.

This research seeks to fill several critical gaps in the existing literature. While prior studies extensively explore the role of healthy dietary habits in reducing chronic disease risks, there remains a lack of targeted research on plant-based diets, particularly fruit and vegetable consumption, within Canada. Inconsistent findings on cancer prevention emphasize the need for further investigation into the effects of varied fruit and vegetable intakes on cancer risks.

Moreover, long-term studies on the health outcomes of food insecurity are limited, highlighting the necessity of longitudinal research to understand its chronic impacts. My research will also address the understudied influence of socioeconomic factors on dietary choices and chronic disease prevalence, particularly within underserved communities, and will explore regional dietary variations across Canada. By incorporating a comprehensive regional analysis of all Canadian provinces and territories, this study will provide granular insights into the nuanced relationship between diet and chronic diseases, bridging gaps in the current understanding and contributing to more effective public health interventions.

2.8. Conclusion

The reviewed literature strongly supports national and international dietary guidelines that advocate for increased fruit and vegetable consumption as a preventive measure against chronic diseases. However, the mitigation of food insecurity must also be a priority to ensure equitable access to these dietary benefits across different socioeconomic groups. By addressing both dietary intake and food security, policymakers and public health officials can better combat the pervasive impact of chronic diseases globally.

In conclusion, the comprehensive review of literature establishes a significant correlation between diet quality and the prevalence of chronic diseases in Canada. Key tools like the Healthy Eating Index-Canada 2010 (HEI-C 2010) have been instrumental in assessing diet quality and its relation to chronic disease risk. Economic analyses highlight the substantial costs associated with nonadherence to dietary guidelines, reinforcing the importance of public health strategies that advocate for healthier eating habits. The literature suggests that adopting dietary patterns akin to the Mediterranean and Nordic diets could notably reduce chronic disease prevalence in Canada.

The review also points to current trends in dietary patterns and physical activities that are contributing to an increase in chronic diseases across the country. There is an urgent need for policy action and the implementation of community-based primary prevention interventions, particularly in regions with significant ethnic and regional variations, such as northern Canada. While the Canadian Healthy Eating Strategy and the updated Food Guide represent positive steps, ongoing effort and adaptation are necessary to effectively address these health challenges (Lix et al., 2010).

Moreover, the unique challenges faced by populations in northern Canada, especially among Aboriginal groups, underscore the need for tailored interventions and policies that are sensitive to cultural and regional differences. This review emphasizes the need for further research in these areas to develop a more nuanced understanding of these correlations and to formulate effective public health strategies.

Overall, the literature indicates a clear link between sustainable diets and the prevalence of chronic diseases in Canada. The rising prevalence of diseases such as diabetes, obesity, and heart disease is closely linked to changes in dietary and physical activity patterns, influenced by economic growth and cultural shifts. Governmental policies, including the Canadian Healthy Eating Strategy, are crucial in addressing these issues. However, the persistence of high economic burdens due to poor-quality diets highlights the continued necessity for enhanced public health efforts to promote healthier eating habits, which are vital for improving public health outcomes in Canada.

This literature review clearly establishes the correlation between sustainable diets and the prevalence of chronic diseases in Canada. It underscores the complex interplay between diet, chronic disease prevalence, and the socio-economic and cultural context, highlighting the necessity for multifaceted and culturally aware health policies and interventions. The rise in chronic diseases is intricately linked to dietary patterns and lifestyle choices, with the Canadian Healthy Eating Strategy marking a significant step towards addressing these health issues. However, this strategy requires continuous adaptation and the implementation of region-specific interventions, especially in northern Canada, to be truly effective.

Further research is essential to understand the variations in chronic diseases and risk factors among different Aboriginal groups, particularly in northern Canada. There is an urgent need for more comprehensive data collection and analysis to obtain a clearer picture of chronic disease prevalence and its determinants. Such research will be instrumental in developing more effective, culturally sensitive health policies and interventions tailored to the needs of diverse populations.

The collective findings from the studies highlight the significant impact of diet quality on the prevalence of chronic diseases in Canada. Despite observed improvements in dietary habits, a substantial portion of the Canadian population continues to consume diets of poor quality, contributing to a considerable economic burden associated with chronic diseases. The emphasis

on whole, nutrient-rich foods and the reduction in processed, nutrient-poor foods is critical for addressing this public health issue. These findings indicate the necessity for continued and enhanced efforts to promote healthier eating habits among Canadians to further reduce the prevalence and economic impact of chronic diseases.

While the reviewed literature extensively explores the correlation between healthy and quality dietary habits and chronic diseases, a significant gap is evident in the examination of a plant-based diet, especially fruits and vegetables, in Canada. The literature review identifies substantial evidence supporting the role of plant-based diets in reducing chronic diseases like cardiovascular diseases and diabetes but notes inconsistent findings on cancer prevention, suggesting a need for targeted research on the impact of varied fruit and vegetable intakes on cancers. It also highlights a lack of long-term studies on the health outcomes of food insecurity, emphasizing the necessity for longitudinal research to understand its chronic effects. Moreover, the review calls for further investigation into how socioeconomic factors influence dietary choices and chronic disease rates, particularly within underserved communities, and stresses the need for detailed studies on regional and ethnic dietary variations, especially in Canada. This research aims to fill this gap by employing a multivariate logit model to assess the correlation between fruit and vegetable consumption and chronic conditions, focusing on the period from 2004 to 2020. This time frame is critical as it encompasses the rising trend of sustainable eating practices. Additionally, unlike previous studies, this research will provide a comprehensive regional analysis across all Canadian provinces and territories, offering insight into the nuanced relationship between diet and chronic diseases at a more granular level.

Chapter 3 - Methodology

This chapter outlines the statistical models and analytical strategies employed to investigate the relationship between fruit and vegetable consumption and the prevalence of chronic diseases in Canada. The analysis utilizes logistic regression models, incorporating univariate, multivariate, and province-specific approaches, to provide a comprehensive understanding of the associations.

Several previous studies have utilized the Canadian Community Health Survey (CCHS) dataset to explore various aspects of fruit and vegetable consumption and its relationship with health outcomes. For instance, McMartin, Jacka, and Colman (2013) examined associations

between fruit and vegetable intake and mental health disorders using logistic regression models across five waves of the CCHS (2000–2009). Their findings highlighted the protective effects of higher intake against depression and other mental health issues. Similarly, Quadir and Akhtar-Danesh (2010) investigated fruit and vegetable consumption among Canadian ethnic populations and its association with long-term diseases, focusing on ethnic disparities and the risks associated with inadequate consumption. Ekwaru et al. (2017) leveraged CCHS data to estimate the economic burden of inadequate intake of fruit and vegetables on chronic disease prevalence, using population-attributable fractions to quantify the cost implications. Additionally, Colapinto et al. (2018) analyzed trends and sociodemographic correlates of consumption, employing logistic regression to identify predictors of consuming fruit and vegetables five or more times daily as a proxy for diet quality.

While these studies have significantly contributed to understanding fruit and vegetable consumption and its impacts, this research offers distinct methodological and analytical advancements. Unlike prior work, which often focused on specific subsets of health outcomes or demographic groups, this study spans a broader timeframe, analyzing 16 years of CCHS data (2004–2020) to investigate the relationship between consumption and chronic disease prevalence across the Canadian population. The chronic diseases of interest include diabetes, high blood pressure, heart disease, and cancer, which are examined both collectively and individually to provide a comprehensive view of the association.

Methodologically, this study employs logistic regression models, similar to some previous analyses. However, it integrates both cross-sectional and longitudinal perspectives to capture temporal patterns and trends, which have been underexplored in earlier research. Additionally, the models are adjusted for a comprehensive set of demographic, socioeconomic, and lifestyle variables, offering a more nuanced understanding of the relationship between fruits and vegetable consumption and chronic diseases.

Furthermore, this study delves into the variability of associations across subgroups, such as age, income, and provincial regions, which allows for the identification of potential disparities and contextual factors influencing the impact of consumption on chronic disease outcomes. The inclusion of more recent data also enables an evaluation of the effectiveness of public health interventions, such as the 2019 update to Canada’s Food Guide, in shaping dietary habits and their subsequent effects on health.

By addressing gaps in temporal coverage, analytical depth, and subgroup variability, this study not only complements but also extends the existing body of research. The findings are expected to provide actionable insights for policymakers and public health practitioners aiming to mitigate chronic disease prevalence through targeted dietary recommendations and interventions.

3.1. Research Design

This study uses a quantitative research design to analyze the relationship between fruit and vegetable consumption and chronic disease prevalence in Canada, focusing on diabetes, high blood pressure, heart disease, and cancer. Drawing on 16 years of Canadian Community Health Survey (CCHS) data (2004–2020), the research combines cross-sectional and longitudinal perspectives to examine patterns and trends. Logistic regression models are used to identify associations between dietary habits and chronic diseases, adjusting for demographic, socioeconomic, and lifestyle factors. While causation cannot be established due to the dataset's observational nature, the large sample size and comprehensive variables provide robust insights into how dietary patterns and contextual factors influence chronic disease prevalence across diverse Canadian populations.

3.2. Econometric Model

This section outlines the statistical models employed to analyze the relationship between fruit and vegetable consumption and the prevalence of chronic diseases. Logistic regression was chosen due to the binary nature of the dependent variables, representing whether an individual reported being diagnosed with a specific chronic disease. Two primary types of models were used - Univariate and Multivariate models.

3.2.1 General Model Specification

The logistic regression model can be expressed as

$$\text{logit}(P(Y_i = 1)) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta \square X \square_i + \varepsilon_i \qquad (1)$$

Where

- $P(Y_i = 1)$: The probability of an individual i being diagnosed with a specific chronic disease.
- $X \square_i$: Independent variables, including fruit and vegetable consumption categories, demographic variables, socioeconomic indicators, and lifestyle factors.

- β_0: The intercept term.
- β□: Coefficients representing the effect of each independent variable on the probability of having the disease.
- ε_i: Error term capturing unexplained variation.
- i: Represents the individual observation in the dataset.
- k: Represents the different variables (or predictors) included in the model.

This model was applied separately to each chronic disease: diabetes, high blood pressure, heart disease, and cancer. The outcome variable Y is binary (1 = diagnosed, 0 = not diagnosed) The model will assess the impact of fruit and vegetable consumption on the likelihood of chronic disease diagnosis. The analysis adjusts for potential confounders to isolate the effect of fruit and vegetable consumption.

3.2.2 Types of Models

3.2.2.1. Univariate Model

A univariate logistic regression was first run for each chronic disease, using only fruit and vegetable consumption categories (fru_veg_cat) as the independent variable. This model highlights the direct association between dietary habits and disease prevalence without adjusting for confounders.

$$\text{logit}(P(Y_i = 1)) = \beta_0 + \beta_1(\text{fru\_veg\_cat}) + \varepsilon_i \qquad (2)$$

3.2.2.2. Multivariate Model

To account for potential confounding factors, multivariate logistic regression models were employed. These models included additional control variables across four domains.

- Demographic variables - Age (i.age), sex (i.sex), marital status (i.marital_sts).
- Socioeconomic variables - Education (i.education), household income (i.hh_inc).
- Lifestyle behaviors - Alcohol consumption (i.alcohol).
- Year effects - A categorical variable (i.year) to account for temporal variation.

The multivariate model specification is

$$\text{logit}(P(Y_i = 1)) = \beta_0 + \beta_1(\text{fru\_veg\_cat}) + \beta_2(\text{Control Variables}) + \varepsilon_i \qquad (3)$$

3.2.3. National Analysis

The given univariate (2) and multivariate (3) models were run for the entire sample to test the effects of consumption on chronic diseases.

3.2.4. Provincial Analysis

To explore regional differences in the relationship between dietary behaviors and chronic diseases, the models were run separately for each province.

For each province:

1. **Univariate Model** - Disease prevalence was modeled against fru_veg_cat.
2. **Multivariate Model** - Control variables were added to assess adjusted relationships.
3. **Food-Type-Specific Model** - Disease prevalence was analyzed using specific fruits and vegetables (fru_jui, fruits, salad, potato, carrot, veg) as independent variables.
4. **Comprehensive Model** - Included both specific fruit and vegetable types and control variables.

3.2.5. Age and Income Analysis

The univariate and multivariate models were tested for each age category and income group to see the demographic and socioeconomic variations in how consumption affects chronic diseases.

3.2.6. Food Insecurity Analysis

To test the food insecurity effects on chronic diseases the model was modified as follows,

Univariate model specification as,

$$\text{logit}(P(Y_i = 1)) = \beta_0 + \beta_1(\text{food\_insecsome2}) + \varepsilon_i \quad (4)$$

Where the independent variable is now represented by the household food insecurity status variable.

And multivariate model specification as,

$$\text{logit}(P(Y_i = 1)) = \beta_0 + \beta_1(\text{food\_insecsome2}) + \beta_2(\text{Control Variables}) + \varepsilon_i \quad (5)$$

Where, food insecurity variable is followed by demographic, socioeconomic, lifestyle, and year effect variables.

3.3. Estimation Strategy

3.3.1. Clustering of Standard Errors

The analysis employs clustering of standard errors by the year to adjust standard errors for potential correlations among observations collected in the same survey year, addressing heteroskedasticity and within-year autocorrelation for robust statistical inference.

Yearly clustering accounts for shared influences, such as health policies, economic conditions, or public health campaigns, that may impact chronic disease prevalence or dietary habits. It controls for unobserved, year-specific effects, ensuring more accurate estimates of variability and reducing bias in standard errors.

In repeated cross-sectional data, year-specific dependencies, such as sampling variations or temporal trends, can affect observations. By clustering standard errors at the year level, this approach improves the reliability of estimates and confidence intervals while reflecting real-world dependencies in the data.

3.3.2. Multilevel Logistic Regression Models

Given the hierarchical nature of the data, with individuals nested within provinces, we employ multilevel logistic regression models to account for clustering at the provincial level. This approach enables us to capture both individual-level predictors and regional variations in chronic disease prevalence.

3.3.3. Random Intercepts

Each model includes random intercepts for provinces to account for unobserved regional factors that may influence health outcomes, such as healthcare access, cultural dietary patterns, socioeconomic conditions, or provincial health policies. By allowing the baseline likelihood of chronic disease prevalence to vary across provinces, the random intercepts adjust for differences that are not explicitly captured by the variables in the model. This approach ensures that unobserved heterogeneity at the regional level is accounted for, improving the accuracy and validity of the estimated relationships between fruit and vegetable consumption and chronic diseases. It allows the model to isolate the effects of individual-level predictors while acknowledging the influence of provincial variability.

3.3.4. Cross-Sectional Nature of the Data

Although the dataset spans 16 years, the dataset used in this study is cross-sectional in nature, capturing individual-level data at distinct time points without tracking the same individuals over time. Each observation represents a unique individual surveyed within a specific year, and there are no repeated measures for the same individuals across years. While the dataset spans multiple years and allows for the examination of population-level trends over time, the

lack of continuity in individual observations makes it unsuitable for panel analysis. Instead, the data provides independent cross-sectional snapshots for each year, enabling an analysis of associations between dietary habits, demographic factors, and chronic disease prevalence across the population, rather than longitudinal changes within individuals.

3.4. Control Variables

To control for potential confounding factors, the following variables were included in the multivariate models.

- Demographic Variables - Age, Sex, Marital Status
- Socioeconomic Variables - Household Income, Education
- Lifestyle Variables - Alcohol Consumption
- Temporal and Regional Controls
    - Province of Residence - Models were run separately for each province to explore regional differences.
    - Year - Included as a categorical variable (i.year) to account for temporal variation. Including i.year can help control for certain yearly factors such as, public health policies, economic shifts, or societal trends. It is also helpful in observing trends over time or accounting for any common shifts in diseases across years. Lastly, year fixed effects help control for unobserved factors that change yearly but are constant across individuals within a given year, thus reducing potential omitted variable bias.

Reason for excluding bmi

BMI was excluded from the model due to its potential overlap with fruit and vegetable consumption in influencing chronic diseases. As BMI reflects dietary patterns and may act as an intermediate variable in the diet-disease pathway, including it could diminish the unique contribution of fruits and vegetable consumption and complicate interpretation. Excluding BMI ensures the analysis focuses on the direct impact of dietary habits on disease risk, avoids multicollinearity, and provides a clearer assessment of dietary effects without conflating them with BMI's intermediary role.

3.5. Robustness Checks

To ensure the reliability of findings, several robustness checks were conducted.

1. **Alternative Dependent Variables**: Separate models were estimated for diabetes, high blood pressure, heart disease, and cancer to verify consistency across chronic diseases.
2. **Food-Type-Specific Analysis**: Models included specific fruit and vegetable types (e.g., fruit juice, salads, carrots) to evaluate their distinct effects.
3. **Alternative Model Specifications**: The impact of including or excluding control variables (e.g., BMI, income) was tested for sensitivity.
4. **Redefining Consumption Categories**: Different categorizations for fru_veg_cat (e.g., quartiles, equal intervals) were tested to ensure robust results.
5. **Regional and Demographic Subgroups**: Models were stratified by province, age, gender, and income to explore heterogeneity across regions and populations.
6. **Excluding Specific Years**: Certain years with outliers or unusual trends were excluded to test the stability of findings.

These checks validated the consistency and robustness of the results, providing deeper insights into dietary impacts on chronic disease risk.

3.6. Summary

The use of univariate and multivariate models, combined with provincial and food-type-specific analyses, provides a comprehensive framework to assess the relationship between fruit and vegetable consumption and chronic diseases. These models allow for both broad national-level insights and nuanced regional and dietary analyses. However, given the observational nature of the data, the results should be interpreted as associations rather than causal effects.

3.6.1. Methodological Strengths

The use of univariate models captures the direct association between fruit and vegetable consumption and each chronic disease, establishing a baseline understanding of these dietary impacts. Multivariate models build on this by adjusting for potential confounders, allowing for a more nuanced interpretation of the relationship between diet and disease, accounting for factors like age, income, and education. Additionally, provincial analyses illuminate regional differences, contextualizing the national findings and offering insights into how local factors may influence health outcomes related to dietary behaviors.

3.6.2. Limitations of the Methodology

While the methodology is robust, it has certain limitations. The cross-sectional design of the dataset restricts the ability to draw causal inferences, as it captures only a single point in time for each individual without tracking changes over time. Additionally, reliance on self-reported dietary and health data may introduce recall or social desirability bias, potentially affecting the accuracy of reported behaviors and health conditions. Lastly, residual confounding from unmeasured factors, such as physical activity or genetic predisposition, may influence the findings, meaning that some important influences on chronic disease risk remain unaccounted for in the analysis.

Chapter 4 - Data

The data utilized in this study plays a central role in addressing the research questions and testing the stated hypotheses. Specifically, the dataset allows for an examination of the relationship between fruit and vegetable consumption and the prevalence of chronic diseases, such as high blood pressure, diabetes, heart disease, and cancer. By analyzing dietary patterns alongside demographic, socioeconomic, and lifestyle factors, the data facilitates a comprehensive understanding of how these elements interact and contribute to health outcomes in Canada.

4.1. Source of Data

The Canadian Community Health Survey (CCHS) is part of a recent federal initiative to provide health information at the regional and provincial levels. It is a cross-sectional survey that collects information related to health status, healthcare utilization, and health determinants for the Canadian population.

Due to its comprehensive nutrition and chronic disease modules, the CCHS is particularly suitable for examining chronic disease prevalence and dietary behaviors. These include detailed questions on fruit and vegetable consumption, food security, and health outcomes, which align closely with the research objectives.

Data collection for cycle 1.1 began in September 2000 and was conducted over 12 months for every alternate year. This helped balance the interviewer's workload and minimize seasonal effects on specific health-related characteristics, such as physical activity. The sample of households was allocated randomly over the 12-month period, and every health region was visited in each collection month.

Initially, the CCHS had a 2-year data collection cycle that consisted of two distinct surveys; the first year (cycle X.1, now referred to as the CCHS-Annual Component) was a general health survey that included a sample of approximately 130,000 Canadians, large enough to allow data to be presented at the level of health regions within each of the ten provinces and three territories. The second year of the data collection cycle (cycle X.2) focused on a specific subject matter or population (e.g., mental health, aging, nutrition), had a total sample of approximately 30,000 individuals, and allowed provincial-level estimates.

Beginning in 2007, data for the CCHS-Annual Component survey began to be collected annually instead of every second year, and the sample size was changed to 65,000 per year. This survey, now called the CCHS-Annual Component, is designed to take about 45 minutes to complete. Among other topics, it includes content modules related to nutrition (e.g., food insecurity, food choices, fruit and vegetable consumption, and maternal experiences).

4.1.1. Target population

The CCHS targets individuals aged 12 or older living in private dwellings. The CCHS covers approximately 98% of the Canadian population aged 12 or older. People living on Indian reserves or Crown lands, residents of institutions, full-time members of the Canadian Armed Forces, and residents of certain remote regions are excluded. These exclusions account for less than 3% of the target population. The three territories were not included in the analyses based on the preliminary file comprising the first half of data collected for cycle 1.1 because data collection in those areas began later than in the rest of the country.

4.1.2. Time Period

The dataset covers the years 2004 to 2020, providing 16 years of data to analyze both cross-sectional and longitudinal patterns providing robust statistical power for the analysis. This time period was selected to focus on consistent and reliable data following the standardization of CCHS data collection practices. The exclusion of earlier years ensures alignment with the research objectives and eliminates potential inconsistencies caused by initial data collection methodologies.

4.1.3. Data Access

The dataset was obtained through restricted access provided by the Statistics Canada Research Data Centre (RDC) program, in affiliation with the McGill University Library. Access

to this data was granted as part of an academic agreement, ensuring secure and confidential handling of sensitive information. The RDC at McGill Library facilitates access to comprehensive datasets, such as the Canadian Community Health Survey (CCHS), for approved academic research purposes under strict privacy and ethical guidelines. The data used in this study is publicly available and anonymized by Statistics Canada, ensuring that no personal identifying information is disclosed. The research will adhere to the ethical guidelines established by Statistics Canada for secondary data analysis. There are no direct ethical concerns regarding the protection of respondent privacy or confidentiality, as the CCHS data is de-identified and aggregated for public use.

4.2. Measures

4.2.1. Independent Variables

Age (age) was assessed using the variable "age" in the dataset. Initially, in the CCHS, this variable had 15 categories, ranging from 12–14 years to over 80 years, reflecting a detailed breakdown of age groups. While this level of granularity provides nuanced insights, it can complicate the interpretation of regression results, especially when examining broad trends in dietary patterns and chronic disease prevalence. To simplify the regression analysis and enhance the clarity of the results, the 15 age categories were reclassified into five broader groups as follows, 12-24 years, 25-39 years, 40-54 years, 55 to 69 years, and over 70 years. This reclassification preserves the key life stages and age-related trends while reducing the model's complexity. The new categories balance granularity and interpretability, ensuring the regression results are more accessible and actionable.

Gender (sex) was analyzed separately in this regression. The whole sample was divided into two parts, one for males and one for females. This was done because the health conditions of men and women differ greatly. Classifying the whole dataset by different genders could reduce bias and make the regression results more significant.

Marital status (marital_sts) is assessed using the variable “marital_sts” in the dataset. This is a categorical variable with four main categories - married, common-law, widowed, separated, or divorced, and single.

Alcohol (alcohol) consumption was assessed using the variable "alcohol" in the Canadian Community Health Survey in 2010. This variable was calculated based on the survey

question "ALC_1". ALC_1 asked the closed question: "During the past 12 months, that is, from one year ago to yesterday, have you had a drink of beer, wine, liquor, or any other alcoholic beverage?" Respondent choices include: 1=yes; 2=no. If ALC_1=2, the respondent did not drink at all in the past 12 months. Alcohol consumption can play a significant role in a person's overall diet and the amount of energy (Calories) they consume. For this series of questions, a "drink" was defined as one bottle or can of beer or a glass of draft, one glass of wine or a wine cooler, or one mixed drink or cocktail with 1.5 ounces of liquor, such as vodka, rum, or gin. Participants aged 12 years or above were asked if they had consumed a drink during the past year.

Income (hh_inc) was assessed using the derived variables" hh_inc," which has six categories: no income; less than $15,000; $15,000 to $29,999; $30,000 to $49,999; $50,000 to $79,000; and $80,000 or more. Total household income before taxes were queried.

Education (education) was assessed using the categorical variable "EDUDR04". It has four categories - less than secondary school graduation, secondary school graduation, other post-secondary education, and post-secondary degree/diploma.

Food-Type-Specific Variables (fru_jui, fruits, salad, potato, carrot, veg) were used in the analysis as independent variables.The following food and drinks are included in the module, 1) fruit juices such as orange, grapefruit or tomato; 2) fruit; 3) green salad; 4) potatoes, not including French fries, fried potatoes, or potato chips; 5) carrots; 6) other vegetables. The question about other vegetables is worded as, "Not counting carrots, potatoes, or salad, how many servings of other vegetables do you usually eat?

The fruit and Vegetable Consumption (fru_veg_cat) component of the CCHS asked participants how often they consumed fruits and vegetables each day based on the fruit and vegetable module in the Behavioural Risk Factor Surveillance System of the United States Centers for Disease Control Prevention (CDC) (2011). The component included the following questions - "Not counting juice, how often do you usually eat fruit?"; "How often do you (usually) eat green salad?"; "How often do you (usually) eat carrots?"; "Not counting carrots, potatoes, or salad, how many servings of other vegetables do you usually eat?". Total fruit and vegetable intake was assessed by combining the responses to questions regarding consumption frequency of fruits (not counting juice), green salad, carrots, potatoes, and other vegetables (excluding potatoes). The score was divided into quartiles for analysis, with the lowest quartile (i.e., least consumption of fruit and vegetables) being the reference category. Fruit and vegetable

intake was assessed. Fruit juices are high in sugar and associated with weight gain and unhealthy dietary habits (Ludwig et al., 2001). Note that the data from this module provide information on the frequency of consumption, rather than on the amount consumed on each occasion, and do not include consumption of vegetables in mixed dishes. The module thus tends to underestimate consumption (Field et al., 1998).

The original dataset included a categorical variable representing fruit and vegetable consumption levels, divided into three categories - less than 5 servings, 5–10 servings, and more than 10 servings per day. However, an examination of the distribution across these categories revealed an imbalance, with a relatively small proportion of individuals falling into the highest consumption group (more than 10 servings). This uneven distribution may contribute to challenges in detecting statistically significant effects for this variable.

To address this issue, the variable was reclassified based on the reported frequency of fruit and vegetable consumption for each observation. The newly defined categories are as follows - Less than 2 servings per day as LOW CONSUMPTION, 2–5 servings per day as MODERATE CONSUMPTION, and More than 5 servings per day as HIGH CONSUMPTION.

This reclassification was implemented to achieve a more balanced distribution across categories, ensuring sufficient representation within each group. A more equitable distribution of observations across categories enhances the statistical power to detect significant relationships and facilitates a more robust analysis of the association between fruit and vegetable consumption and chronic disease outcomes. The revised categorization provides a clearer and more reliable framework for examining these relationships.

Food Insecurity (food_insecsome2) status refers to the condition of households that experience uncertain, insufficient, or inadequate access to food due to financial constraints. Food insecurity is typically measured using a standardized set of survey questions designed to assess the severity and frequency of food-related challenges within a household. Based on the number of positive responses to the questions posed, households are classified as food secure (no indication of any income-related problems of food access), marginally food insecure (some concern or problem of food access), moderately food insecure (compromises in the quality and/or quantity of food consumed) or severely food insecure (extensive compromises including reduced food intake). The old labeling was retained from the survey for the categories -

SECURE, WITHOUT HUNGER, WITH MODERATE HUNGER, and WITH SEVERE HUNGER.

4.2.2. Dependent Variable

The dependent variable in this study represents the prevalence of chronic diseases, focusing on four key conditions - diabetes, high blood pressure, heart disease, and cancer. These conditions are of significant public health concern due to their high prevalence, associated healthcare costs, and substantial impact on quality of life. Each of these variables is binary, indicating whether an individual has been diagnosed with the disease. The variable is coded as - 1 if the individual reports being diagnosed with diabetes by a healthcare professional. 0 if the individual does not report having diabetes.

Diabetes (diabetes) is a metabolic disorder characterized by elevated blood sugar levels due to insufficient insulin production or insulin resistance. It is influenced by dietary habits, particularly the intake of fruits and vegetables, which may improve insulin sensitivity and glycemic control.

High blood pressure (hbp), also known as hypertension, is a condition where the force of blood against artery walls is consistently too high, increasing the risk of heart disease and stroke. A diet rich in fruits and vegetables, which are high in potassium and low in sodium, is known to help regulate blood pressure.

Heart disease (heart_dis) includes conditions such as coronary artery disease, heart failure, and other cardiac issues affecting heart function. Nutritional factors, including high fruit and vegetable intake, are linked to lower cholesterol levels, reduced inflammation, and improved cardiovascular health.

Cancer (cancer) is a broad group of diseases involving abnormal cell growth with the potential to invade or spread to other parts of the body. Diets rich in fruits and vegetables are associated with a lower risk of certain cancers due to their high content of antioxidants, fiber, and phytochemicals.

4.3. Data Cleaning and Preparation

4.3.1. Handling Missing Data

The dataset was evaluated for missing data prior to analysis. Missing values were identified for key variables, including fruit and vegetable consumption, chronic disease

indicators, and demographic factors. A systematic approach was employed to address these missing data. Observations with missing values for key independent or dependent variables were excluded from the analysis to maintain data integrity. For certain demographic or control variables with minimal missingness imputation (e.g., less than 5%), was applied to avoid unnecessary loss of observations.

4.3.2. Sample Restriction

To ensure the validity and reliability of the analysis, the dataset was examined for temporal trends in both chronic disease prevalence and fruit and vegetable consumption. Observations from years prior to 2004 exhibited unusual patterns, including inconsistencies in reporting and abrupt deviations in disease prevalence and dietary behaviors. These anomalies may have been influenced by changes in data collection methods or external factors during earlier years.

As a result, all observations from years prior to 2004 were excluded from the analysis. This restriction ensured a more consistent and representative dataset for assessing the relationship between fruit and vegetable consumption and chronic disease outcomes over time.

4.3.3. Final Dataset

After data cleaning and preparation, the final dataset included 667,033 observations spanning the years 2004 to 2020. These observations represent individuals aged 12 years and older across all Canadian provinces, with complete data for the variables of interest.

4.4. Data Limitations

4.4.1. Coverage Issues

While the dataset broadly represents the Canadian population, certain geographical and demographic groups are underrepresented. For example, data from the three territories (Nunavut, Northwest Territories, and Yukon) were combined into a single region, and specific populations, such as those living on reserves or in remote areas, were excluded. This exclusion may limit generalizability to these groups.

4.4.2. Measurement Bias

The dataset relies entirely on self-reported data, which introduces the potential for measurement bias. Self-reported data on fruit and vegetable consumption may be subject to

recall bias, as participants might not accurately remember or report their dietary habits. There may also be a tendency for individuals to overreport healthy behaviors (e.g., higher consumption of fruits and vegetables) due to social desirability bias.

Chronic disease indicators (e.g., diabetes, high blood pressure, heart disease, cancer) are based on self-reported diagnoses by healthcare professionals. This reliance on self-reporting may result in underreporting for undiagnosed or unrecognized conditions, particularly in populations with limited access to healthcare.

Variables such as BMI, alcohol consumption, and Income category are also self-reported, potentially leading to inaccuracies due to recall errors, misinterpretation of questions, or intentional misreporting.

4.4.3. Other Limitations

The dataset lacks detailed contextual information on factors that may influence diet and health, such as cultural influences, the availability of fruits and vegetables, and local food prices. These missing elements limit the ability to capture a more nuanced understanding of dietary behaviors and their relationship with chronic disease prevalence.

Additionally, the fruit and vegetable consumption data reflect the frequency of consumption rather than the actual quantity. This constraint hinders precise assessment of whether participants meet recommended dietary intake levels.

Furthermore, although the dataset spans multiple years, its cross-sectional design does not allow for definitive conclusions about causality between fruit and vegetable consumption and chronic diseases. As a result, observed associations may be influenced by unmeasured confounding factors.

Chapter 5 - Analysis of Results

This chapter presents a comprehensive analysis of the data, exploring the patterns and relationships between fruit and vegetable consumption and the prevalence of chronic diseases across Canada. It delves into the national and regional variations in dietary habits and their associations with high blood pressure, diabetes, heart disease, and cancer, providing a nuanced understanding of these relationships. The analysis also highlights the influence of demographic, socioeconomic, and lifestyle factors, offering critical context for interpreting the results.

The chapter begins with descriptive statistics, laying the foundation for regression analyses by examining variations in fruit and vegetable consumption and chronic disease prevalence across national, provincial, age, income, and food insecurity levels. Regression analyses then investigate the associations between dietary habits and chronic disease outcomes, both at aggregate and specific fruit and vegetable levels. The findings yield insights into how consumption patterns, food insecurity, and broader socioeconomic factors contribute to health disparities, informing targeted dietary interventions.

5.1. Descriptive Statistics

This section explores the dataset comprehensively, examining patterns, relationships, and nuances within the data. By highlighting variations in fruit and vegetable consumption and chronic disease prevalence across demographic, socioeconomic, and lifestyle factors, this section establishes a critical context for subsequent regression analyses.

5.1.1. National

5.1.1.1. The distribution of fruit and vegetable consumption

Table 5.1.1.1 presents the distribution of fruit and vegetable consumption within the sample population. This distribution categorizes consumption into low, moderate, and high levels, providing a baseline for analyzing dietary habits.

Approximately one-third of the population (32.3%) falls into the low-consumption category, suggesting a limited intake of fruits and vegetables. This group may face increased health risks if lower consumption is, as research suggests, linked to a higher prevalence of chronic diseases.

Table 5.1.1.1. The distribution of fruit and vegetable consumption within the sample

Consumption Level	Observations	Percentage of Sample
Low Consumption	215,333	32.28%
Moderate Consumption	294,854	44.20%
High Consumption	156,846	23.51%
Total	667,033	100.00%

Examining this group's demographics and lifestyle factors could provide valuable insights, as lower consumption may correlate with socioeconomic or lifestyle barriers, such as limited access to fresh produce or lower health literacy.

The most significant portion of our sample, representing nearly 44% of the population, reports moderate consumption of fruits and vegetables. This group provides a critical perspective for understanding the health impacts of intermediate consumption levels. It may serve as a valuable benchmark for comparing low and high-consumption groups. Moderate consumption, which represents a balanced, though not high, intake, could be the most typical dietary pattern within our sample population.

Approximately one-quarter of the population (23.5%) reports high fruit and vegetable intake. This group is significant in assessing the potential protective effects of a high intake on chronic disease prevalence. Higher consumption levels might reflect more substantial access to resources, higher health literacy, or adherence to dietary guidelines set by health organizations. The relatively lower percentage of high consumers, compared to those in the moderate and low groups, suggests that a substantial intake of fruits and vegetables is not yet common across the population and could be influenced by factors such as economic constraints or cultural habits.

Overall, the majority of the sample (76.5%) reports either low or moderate fruit and vegetable intake, underscoring that high consumption levels are not widespread. This gap suggests an opportunity for public health initiatives and educational programs to promote higher consumption levels, especially if our analysis later finds significant protective effects against chronic diseases linked to increased fruit and vegetable intake.

The composition of the sample across these consumption categories may also reflect broader socioeconomic or lifestyle differences. For instance, lower consumption might be associated with lower-income groups or specific age demographics. In comparison, higher consumption may be more prevalent among health-conscious individuals or those with higher education levels. Exploring these correlations further could offer a deeper understanding of barriers to optimal fruit and vegetable intake within different population segments.

In summary, our sample's fruit and vegetable consumption pattern leans toward moderate intake, with substantial portions at both low and high levels. This distribution provides a foundational context for analyzing the impact of dietary patterns on chronic health outcomes, allowing us to assess how varying levels of fruit and vegetable consumption relate to health risks. Understanding the demographic and socioeconomic nuances within these groups will add valuable insight when interpreting regression analyses and the prevalence of chronic diseases in this population.

5.1.1.2. The distribution of each chronic disease

Table 5.1.1.2 presents the prevalence of four chronic diseases—high blood pressure, diabetes, heart disease, and cancer—across the sample population, providing insight into the overall health profile.

Table 5.1.1.2. The distribution of each chronic disease within the sample

Chronic Disease	No		Yes	
	(Observations)	(Percentage)	(Observations)	(Percentage)
High Blood Pressure	524,261	78.60%	142,772	21.40%
Diabetes	616,181	92.38%	50,852	7.62%
Heart Disease	623,876	93.53%	43,157	6.47%
Cancer	629,691	97.67%	14,997	2.33%

The frequency distribution table for chronic disease variables (table 5.1.1.2.) offers insight into the overall health status of the sample population. These results indicate that high blood pressure is the most prevalent condition among the sample, followed by diabetes, heart disease, and cancer.

With over one-fifth of the sample population (21.4%) reporting high blood pressure, this chronic condition is relatively common compared to other chronic diseases in the sample. The high prevalence might suggest underlying lifestyle or demographic factors, such as age, diet, or stress, contributing to elevated blood pressure.

Diabetes affects a smaller but still significant portion of the population, with 7.6% reporting the condition. This indicates that while less widespread than high blood pressure, diabetes is still a notable health issue, potentially linked to dietary patterns, physical activity, and other risk factors that could be explored further in relation to fruit and vegetable consumption.

Heart disease has a similar prevalence to diabetes, affecting 6.5% of the population. This relatively lower frequency suggests that heart disease, while serious, is less common than high blood pressure and may appear predominantly in specific demographic subgroups, such as older individuals or those with comorbidities.

Cancer is the least prevalent chronic disease in the sample, with only 2.3% of individuals reporting a diagnosis. This lower frequency may reflect cancer's often later onset in life or its association with specific genetic, environmental, and lifestyle factors that are less common than those contributing to other chronic diseases like high blood pressure.

This distribution suggests that high blood pressure is the most common chronic condition, with cancer being the least common in this population. The varying prevalence rates

point to potential demographic and lifestyle variations within the sample that could influence the risk of each disease. These patterns provide a foundation for analyzing how factors like fruit and vegetable consumption relate to each condition, helping to identify dietary or lifestyle interventions that could mitigate chronic disease risk within this population.

The table 5.1.1.3. gives a concise view of the distribution of chronic disease status within the sample. The distribution of chronic disease variables in this sample reveals several insights about the health profile of the population.

Approximately 27.8% of the population has at least one chronic disease (CDS = 1), indicating that a sizable portion of the sample experiences chronic health conditions. The majority, 72.2%, do not report chronic diseases, suggesting that most individuals in the sample are relatively healthy based on the chronic disease indicators used.

Regarding the severity and co-occurrence of chronic diseases, for the most severe category, only 0.08% of the population has all four chronic diseases (CDS_4 = 1). This very low prevalence reflects that multiple chronic conditions are rare in this sample. Similarly, the prevalence of having three chronic diseases (CDS_3 = 1) is also low at 1.47%, suggesting that few individuals experience multiple simultaneous chronic conditions. As the number of chronic diseases decreases, the prevalence increases. About 7.3% have exactly two chronic diseases, while 20.2% have only one. This trend suggests that while single chronic conditions are somewhat common, the likelihood of multiple chronic conditions decreases significantly as the count rises.

Nearly 80% of individuals have either no chronic diseases or just one, so this sample appears to be relatively healthy. However, the presence of chronic diseases among nearly a third of the population (27.8%) highlights the importance of monitoring chronic disease prevalence and management strategies within this population. The relatively low prevalence of multiple chronic diseases (two or more) suggests that while chronic conditions are present, severe health burdens from multiple chronic illnesses are not widespread in this sample. This could indicate that most chronic conditions are isolated or managed effectively to prevent escalation.

Given that around 20.2% of individuals have only one chronic disease, a significant population might benefit from early interventions focused on preventing additional chronic conditions. Effective lifestyle interventions or targeted healthcare support could potentially reduce the risk of these individuals progressing to more severe states (e.g., having two or more

chronic diseases). The rarity of multiple chronic conditions might suggest that chronic disease management practices within the population or healthcare accessibility effectively mitigate severe chronic disease co-occurrence.

In summary, this sample population is predominantly healthy, with a majority either free of chronic diseases or managing only one. The lower prevalence of multiple chronic conditions indicates that while chronic diseases are present, they do not frequently compound. This data can support healthcare planning focused on early intervention for individuals with one chronic condition, aiming to prevent progression and manage health outcomes more effectively.

5.1.1.3. Descriptive Analysis of Chronic Disease Prevalence Across Fruit and Vegetable Consumption Levels

The Table 5.1.1.4 examines how chronic disease prevalence varies across fruit and vegetable consumption levels, shedding light on potential protective effects.

High Blood Pressure

Moderate consumption has the highest proportion of individuals with high blood pressure (47.23%), while high consumption shows a lower proportion (21.44%). This pattern suggests that moderate consumption might correlate with higher high blood pressure rates, but high consumption does not follow this trend as closely. Individuals in the high consumption category have a lower percentage with high blood pressure compared to those in the moderate and low consumption groups. This aligns with the hypothesis that higher fruit and vegetable intake may be associated with lower high blood pressure rates.

Diabetes

The high consumption group has a lower proportion of individuals with diabetes (20.45%) compared to the moderate (46.69%) and low (32.86%) groups. This suggests a potential protective trend, where high fruit and vegetable intake correlates with lower diabetes rates.

Heart Disease

The high consumption group has the lowest heart disease prevalence (20.81%), compared to moderate (47.13%) and low consumption groups (32.06%). This pattern suggests a possible protective effect of higher consumption on heart disease prevalence, though moderate consumers still have the highest prevalence.

Cancer

While moderate consumption has the highest proportion of cancer cases (47.05%), high consumption has a somewhat lower prevalence (24.84%), though not as pronounced as in the other diseases. This may suggest that cancer outcomes are influenced by additional factors beyond general fruit and vegetable consumption.

For high blood pressure, diabetes, and heart disease, there appears to be a trend where higher consumption is associated with lower disease prevalence. Cancer shows a less clear pattern, which may require additional covariate adjustment or subgroup analysis to clarify. These preliminary trends support the hypothesis that higher fruit and vegetable intake might reduce the prevalence of certain chronic diseases. Further analysis with multivariate models could confirm if these patterns hold after accounting for confounding factors.

5.1.1.4. Impact of Disease Prevalence Variation on Regression Analysis

However, the variation in prevalence rates across diseases can impact the interpretation and reliability of the regression results in a few ways.

Firstly, it could affect the Statistical Power and the Precision of the model. As High Blood Pressure has a relatively larger number of cases compared to Cancer, more observations for a condition increase the statistical power, meaning your model can more reliably detect significant effects. For diseases with fewer cases, estimates may be less precise, reflected in wider confidence intervals. The smaller sample of observations may reduce the model's ability to identify a significant association even if an effect exists.

Secondly, it could affect the Model Fit and the Interpretation. Logistic regression models are generally robust to imbalanced outcome classes, but extreme imbalances can affect the fit. For diseases with lower prevalence, the model might focus more on correctly predicting the majority class ("No" cases), potentially leading to biases in estimating the effects of diet on rare outcomes. This can lead to Bias in Coefficient Estimates. The model may underestimate or overestimate the effect of independent variables on the minority class if it cannot adequately capture variations due to the rarity of the outcome. It could also reduce Sensitivity for Rare Outcomes, meaning the model's ability to detect true positives ("Yes" cases) can be diminished. This may cause the estimated impact of fruit and vegetable consumption on low-prevalence diseases to be less reliable.

Lastly, there is a Risk of Overfitting or Underfitting. The model may struggle to generalize well for diseases with few cases, especially with a univariate model, as it may

"overfit" or amplify noise within the small set of positive cases. On the other hand, the model can more easily capture genuine associations for diseases with many cases due to a balanced representation of both classes.

5.1.2. Provincial

This section examines regional differences in fruit and vegetable consumption and chronic disease prevalence across provinces. Most populous provinces are Ontario (34.16%), and Quebec (16.72%), followed by British Columbia (12.33%). Yukon/Northwest Territories/Nunavut (2.43%) and Prince Edward Island (2.27%) seem to be the least populous provinces. Regional differences may reflect varying access to fruits and vegetables, lifestyle factors, and healthcare availability, which could influence chronic disease prevalence. Differences in consumption patterns or access may play a role in interpreting regional disparities in your model.

Table 5.1.4.4. Province Distribution

Province	Frequency	Percent
Newfoundland	18698	2.8
PEI	15158	2.27
Nova Scotia	28288	4.24
New Brunswick	22782	3.42
Quebec	111510	16.72
Ontario	227859	34.16
Manitoba	33643	5.04
Saskatchewan	36396	5.46
Alberta	74203	11.12
British Columbia	82270	12.33
Yukon/NWT/Nunavut	16226	2.43
Total	667033	100

5.1.2.1. The distribution of fruit and vegetable consumption

The table 5.1.2.1. presents the distribution of fruit and vegetable consumption levels across provinces in terms of both frequencies and percentages. Key insights are that Quebec (23.67%) and Ontario (31.58%) have the most significant proportions of individuals in the high consumption category, indicating a higher tendency toward fruit and vegetable intake in these provinces.

Ontario also leads in moderate consumption (32.84%), followed by Quebec (17.11%). These two provinces show a generally higher dietary intake compared to others. Newfoundland

and PEI exhibit higher percentages of low consumption (3.31% and 2.70%, respectively), which may reflect dietary habits or the availability/accessibility of fresh produce in these regions.

This breakdown provides a regional perspective on dietary habits, highlighting areas where interventions or public health campaigns may be needed to encourage higher fruit and vegetable intake.

5.1.2.2. The distribution of each chronic disease

The Table 5.1.2.2. provides the prevalence of diseases by provinces.

High Blood Pressure

Ontario and Quebec exhibit the highest frequencies of high blood pressure cases, comprising 34.96% and 15.94% of the cases, respectively, reflecting their large population sizes. Saskatchewan has a relatively high prevalence rate (6.14%) of individuals with high blood pressure, higher than expected given its population share, suggesting regional health or lifestyle factors may contribute to these outcomes.

Diabetes

Ontario has the largest share of diabetes cases (35.11%), which is proportional to its population size. Nova Scotia shows a relatively high diabetes prevalence (5.65%), which could point to regional risk factors, such as dietary habits, healthcare access, or socioeconomic conditions, influencing diabetes rates.

Heart Disease

Ontario holds the largest share of heart disease cases (35.63%), but Nova Scotia also shows a notable prevalence (5.71%), disproportionately higher than other provinces. Newfoundland and PEI also show slightly higher rates of heart disease, suggesting that certain regional factors, such as dietary habits or genetic predispositions, may influence heart disease rates more strongly in these areas.

Cancer

Ontario has the highest proportion of cancer cases (37.61%), while British Columbia follows with 12.60%. Nova Scotia and New Brunswick display slightly elevated cancer rates (4.53% and 4.23%, respectively) relative to their population sizes, which may warrant further exploration into environmental or lifestyle factors contributing to these figures.

In summary, these tables reveal that chronic disease prevalence is not evenly distributed across provinces, with Ontario consistently showing high absolute case numbers due to its

population size. However, Nova Scotia and Saskatchewan exhibit relatively high rates of chronic conditions like diabetes, heart disease, and high blood pressure, even after accounting for population size. This highlights potential regional influences—whether related to lifestyle, access to healthcare, or environmental factors—that may affect health outcomes across Canada. This analysis suggests that the variation in chronic disease rates across provinces may not only be due to differences in fruit and vegetable consumption but also potentially influenced by factors such as access to healthcare, socioeconomic conditions, and lifestyle habits that vary regionally.

5.1.3. Age

Age plays a crucial role in dietary habits and chronic disease prevalence. This section analyzes these relationships across five age groups.

Table 5.1.3.1. Age Distribution

Age Group	Frequency	Percent
12 to 24 years	103232	15.48
25 to 39 years	128405	19.25
40 to 54 years	135554	20.32
55 to 69 years	170074	25.5
70 years or more	129768	19.45
Total	667033	100

The Largest age group is 55-69 years (25.50%), followed by 40-54 years (20.32%) and 25-39 years (19.25%). Age affects disease risk, with older age groups likely having higher chronic disease prevalence, which makes it relevant to interpret results by age.

5.1.3.1. The distribution of fruit and vegetable consumption

The table 5.1.3.2. presents the distribution of fruit and vegetable consumption levels across different age groups. The 55 to 69 age group has the highest percentage of low consumption (25.98%), followed by the 40 to 54 group (22.54%), suggesting a trend where older adults have higher rates of low consumption.

Table 5.1.3.2. Fruit & Vegetable Consumption by Age Group

Age Group	Low Consumption	Moderate Consumption	High Consumption
12 to 24 years	29517	46162	27553
25 to 39 years	44271	52902	31232
40 to 54 years	48545	56527	30482
55 to 69 years	55936	76082	38056
70 years or more	37064	63181	29523
Total	215333	294854	156846

The highest percentage of moderate consumption is also seen in the 55 to 69 age group (25.80%), followed by those aged 70 and above (21.43%), indicating that moderate consumption is prevalent among older adults.

The 55 to 69 age group again shows the highest percentage of high consumption (24.26%), followed by the 25 to 39 age group (19.91%).

This age-based breakdown provides insights into how dietary habits vary across life stages, with the 55 to 69 group having a broader range of consumption levels. This information is valuable for understanding the role of age in fruit and vegetable intake prior to the regression analysis.

5.1.3.2. The distribution of each chronic disease

The table 5.1.3.3. shows the prevalence of four chronic diseases—high blood pressure, diabetes, heart disease, and cancer—across different age groups.

High Blood Pressure

High blood pressure prevalence increases notably with age. The age group "70 years or more" has the highest proportion (41.73%) of individuals with high blood pressure, followed by those aged 55 to 69 (33.71%). Younger age groups, such as 25 to 39, show low prevalence (2.39%), indicating that high blood pressure is largely an age-related condition.

Diabetes

Similar to high blood pressure, diabetes prevalence increases with age. The "70 years or more" group has the highest diabetes prevalence (43.15%), with the 55 to 69 group also showing a significant prevalence (33.35%). The younger groups (12 to 24 and 25 to 39) have low diabetes prevalence (11.46% and 2.55%, respectively), highlighting age as a key risk factor.

Heart Disease

The likelihood of heart disease increases considerably among older adults, with nearly half (46.77%) of those aged 70 or more reporting heart disease. The 55 to 69 group also has a notable prevalence rate (26.09%). Younger age groups, particularly 25 to 39, exhibit very low heart disease prevalence (1.77%).

Cancer

Cancer prevalence also correlates strongly with age. The 70+ age group has the highest cancer rates (43.60%), while the 55 to 69 group follows with 31.47%. Among younger groups, such as 25 to 39, cancer prevalence remains low (1.89%), again illustrating the age-related risk.

This analysis shows that age is a primary risk factor for all four chronic diseases, with prevalence rates escalating significantly among older age groups. These insights provide an essential foundation for understanding how age may interact with other factors, like fruit and vegetable consumption, to impact chronic disease outcomes in the upcoming regression analyses.

5.1.4. Income

Income disparities affect dietary choices and health outcomes. This section explores fruit and vegetable consumption and chronic disease prevalence across income levels.

Table 5.1.4.1. Household Income Distribution

Household Income	Frequency	Percent
No Income	65951	9.89
< $15,000	129489	19.41
$15,000-$29,999	123567	18.52
$30,000-$49,999	109556	16.42
$50,000-$79,999	227935	34.17
$80,000 or More	10535	1.58
Total	667033	100

Majority of households earn $50,000 to $79,999 annually (34.17%). Income disparities could affect access to fruits and vegetables, which is an important factor in assessing health outcomes.

5.1.4.1. The distribution of fruit and vegetable consumption

Table 5.1.4.2. Fruit & Vegetable Consumption by Household Income

Household Income	Low Consumption	Moderate Consumption	High Consumption
No Income	25236	27358	13357
< $15,000	42686	57988	28815
$15,000-$29,999	41326	54241	28000
$30,000-$49,999	37798	47007	24751
$50,000-$79,999	65627	103276	59032
$80,000 or More	2660	4984	2891
Total	215333	294854	156846

This table presents the distribution of fruit and vegetable consumption levels across different household income groups. The highest income group ($50,000–$79,999) shows the

largest proportion of high consumption (37.64%), followed closely by the same group in moderate consumption (35.03%). This suggests that higher household income may facilitate better access to fruits and vegetables.

Lower income groups (No Income and <$15,000) have a smaller proportion of high consumption (8.52% and 18.37%, respectively), with a greater concentration in low consumption. This indicates potential economic barriers to higher fruit and vegetable intake among lower-income households.

These patterns demonstrate socioeconomic disparities in dietary habits, with higher income groups more likely to consume greater amounts of fruits and vegetables. This distribution provides essential context for understanding the role of socioeconomic factors in dietary choices before further regression analysis.

5.1.4.2. The distribution of each chronic disease

The table 5.1.4.3. provides a detailed view of the prevalence of high blood pressure, diabetes, heart disease, and cancer across different household income groups.

High Blood Pressure

Lower-income groups, particularly those with no income (14.68%) and incomes below $15,000 (27.62%), exhibit a higher prevalence of high blood pressure than those with higher incomes. The prevalence decreases notably in the highest income bracket, with only 1.08% in the "$80,000 or more" group reporting high blood pressure.

Diabetes

Similar to high blood pressure, diabetes prevalence is highest among lower-income groups. The no-income group reports 17.60%, and those earning less than $15,000 show the highest rate (28.71%). In higher-income groups, such as those earning $50,000–$79,999 and above, diabetes rates are comparatively lower, indicating a possible socioeconomic gradient in diabetes prevalence.

Heart Disease

The prevalence of heart disease is also highest among those in lower income groups, with 18.03% for those with no income and 31.15% for the "less than $15,000" group. As income increases, the prevalence of heart disease declines, with only 0.98% in the highest income group ($80,000 or more).

Cancer

The relationship between income and cancer prevalence appears less pronounced compared to the other diseases, although lower-income groups still report slightly higher rates, particularly the less than $15,000 income group (28.62%). The highest income group has a relatively low cancer prevalence (1.18%).

Lower-income groups consistently report higher prevalence rates for chronic conditions like high blood pressure, diabetes, and heart disease. This trend suggests a significant socioeconomic disparity, where individuals in lower-income brackets may have less access to healthcare, healthy foods, and other preventive measures, contributing to these outcomes. Understanding these patterns provides essential context for the influence of socioeconomic factors in your analysis of chronic disease prevalence.

5.1.5. Food Insecurity

Food insecurity is a critical factor influencing dietary patterns and health outcomes. This section examines its relationship with chronic disease prevalence.

Table 5.1.5.1. Distribution of Household Food Insecurity

Food Security Status	Frequency	Percentage (%)	Cumulative Percentage (%)
Secure	546,313	92.73	92.73
Without Hunger	28,376	4.82	97.55
With Moderate Hunger	13,923	2.36	99.91
With Severe Hunger	522	0.09	100.0

The distribution of household food security status reveals that the vast majority of households, 92.73%, are food secure, indicating a high level of food security across the sample. Households experiencing food insecurity are relatively rare, with 4.82% classified as food insecure but without hunger, 2.36% experiencing moderate hunger, and only 0.09% suffering from severe hunger. The cumulative percentages highlight the rarity of severe food insecurity, with nearly 98% of households falling into the secure or without hunger categories. These findings emphasize that while food security is prevalent, addressing the needs of the minority experiencing moderate or severe hunger remains important.

5.1.5.1. The distribution of fruit and vegetable consumption

Table 5.1.5.2. Fruit & Vegetable Consumption by Household Food Insecurity

Food Security Status	Low Consumption (%)	Moderate Consumption (%)	High Consumption (%)	Total (%)
Secure	89.8	93.9	94.57	92.73
Without Hunger	6.24	4.29	3.85	4.82
With Moderate Hunger	3.74	1.78	1.56	2.36
With Severe Hunger	0.23	0.02	0.01	0.09
Total	100	100	100	100

The table presents the distribution of household food security status across three categories of fruit and vegetable consumption: low, moderate, and high. Among food-secure households (92.73% of the total), the majority fall into the moderate consumption category (93.90%), followed closely by high consumption (94.57%) and low consumption (89.80%). For households without hunger (4.82% of the total), there is a notable decrease in the percentage of high fruit and vegetable consumers (3.85%) compared to moderate (4.29%) and low consumption (6.24%). Similarly, in households experiencing moderate hunger (2.36% of the total), low consumption is most prevalent (3.74%), while high consumption is least common (1.56%). Among those with severe hunger (0.09% of the total), low consumption is overwhelmingly dominant (0.23%), with minimal representation in moderate (0.02%) and high consumption (0.01%) categories. These findings suggest a strong association between higher food security and greater fruit and vegetable consumption, with the lowest consumption levels concentrated in food-insecure households.

5.1.5.2. The distribution of each chronic disease

The table 5.1.5.3. reveals distinct patterns between household food security status and the prevalence of chronic diseases, measured across categories for diabetes, high blood pressure, heart disease, and cancer.

For diabetes, 91.30% of individuals with diabetes are in food-secure households, while this percentage drops to 5.41% in households without hunger, 3.19% in those with moderate hunger, and 0.10% in those with severe hunger. Conversely, 92.85% of individuals without diabetes are in food-secure households, and smaller proportions are distributed across food-insecure groups.

For high blood pressure, 93.77% of individuals with high blood pressure are in food-secure households, with lower proportions in households without hunger (3.93%), moderate

hunger (2.24%), and severe hunger (0.07%). Among those without high blood pressure, 92.45% are in food-secure households, and similar declining trends are observed for food-insecure categories.

For heart disease, 93.02% of individuals with heart disease belong to food-secure households, compared to 4.21% in households without hunger, 2.63% in households with moderate hunger, and 0.14% in households with severe hunger. Similarly, 92.71% of individuals without heart disease are in food-secure households, and the percentages decline across food-insecure categories.

For cancer, 93.66% of individuals with cancer are in food-secure households, with 3.71% in households without hunger, 2.46% in moderate hunger households, and 0.17% in severe hunger households. For individuals without cancer, 92.75% are food secure, with similar distributions across food-insecure categories.

These findings highlight that food security correlates with lower chronic disease prevalence. However, as food insecurity severity increases, the percentage of individuals with chronic diseases rises across all categories, suggesting that food insecurity exacerbates chronic disease risks.

5.1.6. Other Demographic Variables Distributions

Table 5.1.4.1 presents the distribution of **Sex** across the sample. Among the respondents, 303,208 observations (45.46%) are male, and 363,825 observations (54.54%) are female. This slight predominance of female respondents may influence certain health outcomes, as sex-based differences in chronic disease prevalence and dietary habits could play a role.

Marital status can also influence lifestyle choices and stress levels, potentially affecting chronic disease prevalence. The distribution is detailed in Table 5.1.4.3. For example, married individuals may exhibit different consumption and health patterns compared to those who are single or widowed. Married individuals comprise 42.79% of the sample, while single individuals account for 28.73%. Meanwhile, those in common-law relationships represent 9.93%, and widowed, separated, or divorced individuals make up 18.55% of the sample.

5.1.7. Socioeconomic and Lifestyle Variables Distributions

Table 5.1.5.1 presents the distribution of **Education** levels among respondents. Most participants (41.84%) are post-secondary graduates, while 23.88% have less than a secondary

education. Higher education levels often correlate with healthier behaviors, potentially influencing chronic disease prevalence, particularly in higher consumption groups.

Lifestyle factors such as alcohol consumption, combined with diet and smoking, can significantly influence chronic disease outcomes. The distributions for **Alcohol** consumption and **BMI** are presented in Tables 5.1.8.1 and 5.1.8.2, respectively. Among respondents, 78.02% report drinking alcohol in the past year. For BMI, 41.35% are classified as having a normal weight, 30.10% are overweight, and 24.17% are classified as obese. Elevated BMI is a well-known risk factor for chronic diseases, which may interact with the effects of fruit and vegetable consumption.

5.1.9. Summary

The descriptive analyses reveal significant patterns and disparities in fruit and vegetable consumption and chronic disease prevalence across demographic, socioeconomic, and lifestyle factors. Key findings indicate that higher consumption levels are associated with lower prevalence of certain chronic diseases, while regional, age, and income disparities highlight structural barriers. Food insecurity emerges as a critical determinant of both dietary habits and health outcomes.

These foundational insights set the stage for regression analyses, which will further clarify the relationships between fruit and vegetable consumption and chronic diseases, controlling for confounding variables. Ultimately, the results aim to inform targeted interventions and policies to promote healthier dietary habits and reduce health disparities across Canada.

5.2. Logit Analysis

Previous analyses of the Canadian Community Health Survey (CCHS) data have provided valuable insights into fruit and vegetable consumption trends among Canadians. For example, Polsky and Garriguet (2020) highlighted a decline in consumption frequency from 5.0 times per day in 2007 to 4.7 times per day in 2014, while also examining patterns by sociodemographic characteristics and body mass index. Similarly, a 2018 Statistics Canada analysis found that females were significantly more likely than males to report consuming fruits and vegetables five or more times per day, and that adolescents aged 12–18 had higher odds of meeting this threshold compared to older adults (Colapinto et al., 2018). These studies have been instrumental in identifying key demographic trends and correlates of fruit and vegetable intake.

However, while previous work has largely focused on consumption patterns and their demographic and socioeconomic correlates, this research shifts the focus to the relationship between fruit and vegetable consumption and chronic disease prevalence. Drawing on 16 years of CCHS data (2004–2020), this study integrates cross-sectional and longitudinal perspectives to examine associations between dietary habits and chronic diseases, including diabetes, high blood pressure, heart disease, and cancer. Using logistic regression models, we identify statistically significant associations between higher fruit and vegetable intake and reduced odds of these conditions, while adjusting for demographic, socioeconomic, and lifestyle factors. Unlike earlier studies, which emphasized trends and consumption disparities, our findings highlight the critical role of dietary habits in chronic disease prevention, offering deeper insights into potential causal pathways and informing public health initiatives.

5.2.1. Diabetes

5.2.1.1. National

The analysis of diabetes risk among Canadians reveals distinct associations with fruit and vegetable consumption, as well as other demographic and socioeconomic factors. To guide interpretation, Table 5.2.1.1.1 presents logistic regression results for both univariate (Model 1) and multivariate models (Model 2). This section examines how moderate and high levels of fruit and vegetable intake relate to diabetes risk while accounting for influences such as education, income, age, sex, and marital status. These findings highlight how dietary habits and social determinants of health collectively shape diabetes prevalence.

Table 5.2.1.1.1. Logistic Regression Results for Probability of Diabetes

	Model 1	Model 2
Constant	-2.475*** (0.092)	-1.795*** (0.067)
Fruit and Vegetable Consumption (fru_veg_cat)		
Moderate Consumption	0.040 (0.076)	-0.022 (0.020)
High Consumption	-0.169** (0.085)	-0.108*** (0.033)
Education Indicators		Yes
Household Income		
Less than $15,000		-0.297*** (0.018)
$15,000-$29,999		-0.559*** (0.026)
$30,000-$49,999		-0.671*** (0.038)
$50,000-$79,999		-0.957*** (0.053)
$80,000 or more		-0.902*** (0.080)
Year Indicators		Yes
Age		

25 to 39 years		-1.641*** (0.120)
40 to 54 years		-0.492*** (0.095)
55 to 69 years		0.429*** (0.093)
70 years or more		0.806*** (0.079)
Sex (Female)		-0.407*** (0.006)
Marital Status		
Common-Law		-0.171*** (0.031)
Widow/Separated/Divorced		-0.018 (0.015)
Single		-0.734*** (0.052)
Province Indicators		Yes
Pseudo R-squared	0.0009	0.1124
Observations	667,033	579,304

Standard errors are reported in parentheses.
Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01

In the multivariate model, moderate fruit and vegetable consumption was not significantly associated with diabetes risk, with a coefficient of -0.022 (p = 0.255), suggesting that moderate intake does not independently influence diabetes odds when other variables are considered. In contrast, in the univariate model, moderate consumption showed a slight positive association (coefficient = 0.040), though this was also not statistically significant. Thus, moderate consumption appears to have minimal influence on diabetes risk.

Conversely, high fruit and vegetable consumption showed a significant negative association with diabetes in both models. In the multivariate model, the coefficient for high consumption was -0.108 (p = 0.001), with an odds ratio (OR) of 0.897, indicating a 10.8% reduction in diabetes odds compared to low consumption. In the univariate model, the effect was stronger (coefficient = -0.169, p = 0.046), but controlling for variables such as education and income reduced the magnitude of the effect. This suggests that the protective association of high consumption overlaps with other health-promoting factors. These findings align with previous research suggesting that higher fruit and vegetable intake may help reduce the risk of type 2 diabetes, although the relationship is often modest and can vary depending on the specific types of fruits and vegetables consumed (Halvorsen et al., 2021).

Education also emerged as a significant protective factor. Higher levels of education are associated with lower odds of diabetes. For example, having completed post-secondary education is linked with an 8.8% reduction in the odds of diabetes (OR = 0.912) compared to those with less than secondary education. The association is also significant for secondary graduates (6.2% reduction, OR = 0.940) and those with other post-secondary education (9.2%

reduction, OR = 0.908). This pattern suggests that education may provide protective benefits, potentially by increasing health literacy, access to healthier food choices, or financial resources that support better overall health. In the multivariate model, the coefficients for education remained statistically significant, indicating a robust relationship between education and lower diabetes risk that persists even after controlling for other factors.

A strong income gradient was also observed in diabetes risk, with higher household incomes associated with significantly reduced odds of diabetes. For instance, those earning $50,000-$79,999 have a 61.6% lower odds of diabetes (OR = 0.384) compared to those earning less than $15,000. Similarly, the highest income group ($80,000 or more) has 59.4% lower odds (OR = 0.406). These results suggest that income significantly influences access to resources like healthcare and healthier foods, which play a critical role in diabetes prevention.

Age emerged as one of the most substantial risk factors for diabetes. Individuals aged 70 years or older have a 123.9% higher odds of diabetes (OR = 2.239) compared to those under 25, underscoring that diabetes risk increases significantly with age. Individuals in the 55-69 age group also have a notably higher risk, with a 53.5% increase in odds (OR = 1.535). Conversely, younger age groups (25 to 39 and 40 to 54 years) show substantially lower odds of diabetes, reinforcing that diabetes is more prevalent in older populations. These findings are consistent with the well-documented link between aging and increased susceptibility to chronic diseases, including diabetes. The age-related effect remained strong across both the univariate and multivariate models, emphasizing age as a major independent factor in diabetes risk.

The analysis also indicated a significant difference in diabetes risk by sex. Being female is associated with a 33.5% lower odds of diabetes (OR = 0.665) compared to males, which may reflect gender differences in biological risk factors, health behaviors, or disease management. This finding aligns with some epidemiological research showing that men may have higher diabetes prevalence, potentially due to differing lifestyle factors, metabolic risks, or healthcare utilization patterns between men and women (Sujata & Thakur, 2021). The protective association with being female persisted even after controlling for other demographic, socioeconomic, and lifestyle variables.

Marital status was also found to be an independent factor in diabetes risk. Being single was associated with a 52.0% lower odds of diabetes (OR = 0.480) compared to being married.

This may reflect lifestyle differences, as single individuals could have distinct healthcare-seeking behaviors or dietary habits that reduce diabetes risk.

In summary, high fruit and vegetable consumption consistently reduced diabetes risk, with income, education, and age emerging as critical factors. These findings highlight the complex interplay between lifestyle and socioeconomic determinants in shaping diabetes prevalence.

5.2.1.2. Provincial

The analysis of diabetes risk and fruit and vegetable consumption across Canadian provinces underscores significant regional variations that have implications for tailored public health strategies. This discussion highlights notable provincial patterns and emphasizes the importance of both aggregate dietary habits and specific food types.

The table 5.2.1.2.1. presents the regression results for British Columbia. High fruit and vegetable consumption reduced diabetes odds by 15.6% (OR = 0.84, p = 0.035), while moderate consumption showed a 12.4% reduction (OR = 0.88, p = 0.033). Disaggregated analysis demonstrated that fruit juice offered the most robust protective effect, reducing diabetes odds by 27.6% (OR = 0.72, p < 0.001), while general vegetables also provided significant benefits. However, starchy items such as potatoes and carrots were associated with increased diabetes odds, suggesting the need to emphasize low-glycemic vegetables in dietary recommendations. The observation that starchy vegetables were associated with increased diabetes odds aligns with research suggesting that the glycemic index and glycemic load of foods can influence diabetes risk (Muraki et al., 2013). This underscores the importance of considering not just overall fruit and vegetable intake, but also the specific types of produce consumed when developing dietary guidelines for diabetes prevention.

Table 5.2.1.2.1. Logistic Regression Results for Probability of Diabetes in British Columbia

	Model 1	Model 2
Constant	-2.622*** (-25.99)	-1.831*** (-20.25)
Fruit and Vegetable Consumption (fru_veg_cat)		
Moderate Consumption	0.00705 (0.07)	-0.124* (-2.13)
High Consumption	-0.112 (-1.01)	-0.170* (-2.11)
Education Indicators		Yes
Household Income Indicators		Yes
Year Indicators		Yes
Age Indicators		Yes

Sex Indicators		Yes
Marital Status Indicators		Yes
Observations	82270	66867

Standard errors are reported in parentheses.
Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01

Quebec exhibited the strongest protective effects of high fruit and vegetable consumption. This can be seen in the table 5.2.1.2.2. In the unadjusted model, high consumption reduced diabetes odds by 39% (OR: 0.61, $p < 0.001$), and even after adjustments for socioeconomic and demographic variables, the protective effect remained significant at 14% (OR: 0.86, $p < 0.001$). The higher intake levels consistently reduced risk emphasizing the importance of increasing overall consumption. Notably, higher education and income were inversely associated with diabetes risk, with wealthier and more educated individuals benefiting from both better dietary patterns and improved access to health resources. Fruit juice again emerged as a protective factor, while potatoes showed a slight increase in diabetes odds, likely due to their high glycemic index.

In New Brunswick, high aggregate fruit and vegetable consumption reduced diabetes odds by 19% in the unadjusted model (OR = 0.81, $p < 0.05$), though this effect became non-significant in the multivariate model, likely due to the influence of alcohol consumption and income. Alcohol use, in particular, was associated with a 63% increase in diabetes odds, highlighting its substantial impact on disease risk. Specific food analyses showed that fruit juice significantly reduced diabetes risk by 16% (OR = 0.84), while potatoes increased odds by 23% (OR = 1.23). These results suggest that focusing on low-glycemic, nutrient-dense produce like fruit juice and general vegetables may be more effective for diabetes prevention than simply increasing overall fruit and vegetable intake.

Table 5.2.1.2.2. Logistic Regression Results for Probability of Diabetes in Quebec

	Model 1	**Model 2**
Constant	-2.363*** (-42.44)	-2.261*** (-21.60)
Fruit and Vegetable Consumption (fru_veg_cat)		
Moderate Consumption	-0.139*** (-7.81)	-0.037 (-1.93)
High Consumption	-0.389*** (-13.16)	-0.138*** (-5.18)
Education Indicators		Yes
Household Income Indicators		Yes
Year Indicators		Yes
Age Indicators		Yes
Sex Indicators		Yes

Marital Status Indicators		Yes
Observations	111510	106366

Standard errors are reported in parentheses.
Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01

In Manitoba, high fruit and vegetable consumption showed a marginally significant protective effect ($p \approx 0.05$) in the base model, indicating that higher intake levels may offer some protection against diabetes. Disaggregated analysis revealed that fruit juice significantly reduced diabetes odds, while starchy vegetables like potatoes and carrots were associated with increased risk. Newfoundland showed a 38.4% increase of having diabetes with the consumption of potatoes.

The results here reinforce the idea that dietary quality, specifically the types of fruits and vegetables consumed is more critical than quantity alone.

In Prince Edward Island, aggregate fruit and vegetable consumption showed no significant association with diabetes odds. However, disaggregated analysis highlighted that fruit juice reduced diabetes odds by 22.6% (OR = 0.774), while potatoes and carrots increased risk. The protective effect observed for fruit juice is noteworthy and somewhat surprising. It contrasts with findings from other studies, such as the Nurses' Health Study II, which found that fruit juice consumption was associated with an increased risk of type 2 diabetes (Bazzano et al., 2008). The reasons for this discrepancy are not clear from the information provided and may warrant further investigation.

Control variables such as income were particularly influential; individuals earning above $80,000 showed a dramatic 76% reduction in diabetes odds (OR = 0.24), underscoring the critical role of socioeconomic factors in mitigating diabetes risk.

In Ontario, high fruit and vegetable consumption was associated with a 13.7% reduction in diabetes odds ($p < 0.01$) after adjusting for socioeconomic and demographic factors. Fruit juice and non-starchy vegetables emerged as significant protective foods, reducing diabetes odds by 26.3% and 9.9%, respectively. Conversely, potatoes increased odds by 29.6% (OR = 1.296), further highlighting the adverse impact of starchy vegetables.

Income consistently emerged as a significant factor across provinces. Higher-income individuals had substantially lower diabetes odds, likely due to better dietary quality, access to healthcare, and healthier lifestyle choices. For example, in Saskatchewan, individuals earning $30,000–$49,999 had 53% lower diabetes odds compared to those in the lowest income group.

Education also played a protective role, with higher levels of education consistently linked to healthier dietary habits and lower diabetes risk, as seen in Quebec and Manitoba.

Alcohol consumption was a notable predictor in several provinces. For instance, in New Brunswick, alcohol use increased diabetes odds by 63%, emphasizing its considerable impact on health outcomes.

While aggregate fruit and vegetable consumption offers protective benefits against diabetes, the type of produce consumed plays a critical role. Fruit juice consistently demonstrated the strongest protective effect, likely due to its antioxidant and polyphenol content, provided it is consumed without added sugars. On the other hand, starchy vegetables like potatoes and carrots were consistently associated with increased diabetes odds, likely due to their high glycemic indices and potential to elevate blood sugar levels.

Socioeconomic and lifestyle factors such as income, education, and alcohol use significantly influenced outcomes, often mediating or amplifying the effects of fruit and vegetable consumption. Addressing these broader determinants of health, alongside targeted dietary recommendations emphasizing low-glycemic, nutrient-dense produce, could more effectively reduce diabetes risk at the population level.

To optimize public health strategies, interventions should promote the consumption of non-starchy vegetables and low-sugar fruits while addressing socioeconomic barriers such as income inequality and food insecurity. Tailored approaches, including subsidies for fresh produce, education on cost-effective dietary practices, and programs to reduce alcohol consumption, can further enhance these efforts. Provinces like British Columbia and Quebec serve as examples of how combining high fruit and vegetable consumption with favorable socioeconomic conditions can yield significant health benefits.

5.2.1.3. Age

The table 5.2.1.3.1. shows the relationship between fruit and vegetable consumption and diabetes risk across age groups, revealing distinct patterns. In younger adults (12–24 years), moderate consumption was associated with a 28.8% increase in odds of diabetes in the unadjusted model, though this reversed to a 6.5% reduction after adjustment (both not statistically significant). High consumption showed a marginal protective effect with a 9.9% reduction in odds ($p = 0.066$). For adults aged 25–39 years, high consumption unexpectedly correlated with a 13.9% increase in odds ($p = 0.066$), likely due to reverse causality. Middle-aged

adults (40–54 years) demonstrated a protective trend, with high consumption reducing odds by 10.3% ($p = 0.052$). The protective effects strengthened in older age groups: adults aged 55–69 years saw a 21.0% reduction in odds with high consumption in unadjusted models, though this attenuated to 9.9% ($p = 0.011$) after adjustment. Among adults aged 70+, high consumption reduced odds by 23.7% ($p < 0.001$) in unadjusted models and 15.4% ($p < 0.001$) in adjusted models.

In younger adults (12–39 years), the relationship between fruit and vegetable consumption and diabetes risk is minimal or inconsistent, likely due to low baseline diabetes prevalence and stronger influences of factors like genetics and physical activity. Surprisingly, some models suggest a marginal positive association between high consumption and diabetes in the 25–39 age group, potentially due to reverse causality, where individuals with prediabetes increase their intake following medical advice. Li et al. (2014) conducted a meta-analysis published in BMJ Open, which showed inconsistent results for the association between fruit and vegetable intake and diabetes risk in younger age groups. In contrast, middle-aged adults (40–54 years) exhibit modest reductions in diabetes risk with high consumption, signaling the growing role of dietary patterns during this transitional phase. The protective effects become most pronounced in older adults (55+ years), where high consumption consistently shows significant reductions in diabetes risk, emphasizing the critical role of diet in managing diabetes at later stages of life.

These findings underscore the importance of age-specific public health strategies to maximize the impact of dietary interventions. For younger adults, the focus should be on cultivating lifelong healthy eating habits through education and early adherence to dietary guidelines. Middle-aged adults can benefit from targeted programs emphasizing high fruit and vegetable intake to mitigate rising diabetes risk. For older populations, interventions should promote both moderate and high consumption levels, making dietary improvements accessible and impactful. Future research should investigate the mechanisms behind these age-specific effects, explore long-term impacts of dietary patterns, and analyze variations within age groups by demographic and socioeconomic factors to refine strategies for diabetes prevention.

5.2.1.4. Income

The table 5.2.1.4.1. highlights income-specific patterns in the relationship between fruit and vegetable consumption and diabetes risk. In lower-income groups, moderate consumption

often increases diabetes odds, such as a 15.2% increase in the "No Income" group and an 8.2% increase in the "Less than $15,000" group in unadjusted models. However, high consumption generally shows protective effects, such as a significant 8.1% reduction in the "Less than $15,000" group after adjustments. In middle-income groups, high consumption demonstrates significant reductions in diabetes odds, including 17.1% in the $15,000–$29,999 group and 9.2% in the $30,000–$49,999 group after adjustment. For higher-income groups, the protective effects of high consumption are stronger and more consistent, with reductions of 18.8% in the $50,000–$79,999 group and 9.7% in the $80,000 or more group in adjusted models. Moderate consumption shows mixed results, often with non-significant effects in higher-income groups. These findings underscore the influence of income on dietary impact and the need for targeted interventions to promote high fruit and vegetable consumption, particularly in low-income populations.

The relationship between fruit and vegetable consumption and diabetes risk varies across income groups, with high consumption consistently showing the strongest protective effects, particularly in adjusted models. In low-income groups, moderate consumption often increases diabetes risk in unadjusted models, likely due to confounding factors like older age and poorer healthcare access, while high consumption becomes modestly protective after adjustment. Middle-income groups benefit the most from high consumption, with reductions in diabetes odds up to 18.8% in the $50,000–$79,999 group, alongside smaller but significant effects for moderate consumption. In high-income groups, the protective effect of high consumption persists but is less pronounced, possibly due to a ceiling effect where other healthy behaviors reduce baseline risk. Covariates such as age, education, and alcohol consumption play significant roles, with higher education and younger age consistently linked to lower diabetes odds. These findings emphasize the importance of addressing systemic disparities in access to quality food and healthcare, particularly for low-income populations, while promoting high fruit and vegetable consumption across all income levels. This aligns with findings from the Canadian Community Health Survey, which demonstrated a graded association between income and diabetes prevalence, with individuals in lower income groups facing significantly higher odds of type 2 diabetes even after adjusting for socio-demographic and lifestyle factors (Dinca-Panaitescu et al., 2005). These disparities likely reflect compounding influences such as

older age, poorer healthcare access, and other unmeasured confounders in low-income populations.

Policy recommendations to reduce diabetes risk should prioritize promoting high fruit and vegetable consumption across all income groups, with targeted efforts to make this more accessible and affordable for low- and middle-income households. Campaigns should encourage higher daily intake, emphasizing "high consumption" as most effective, and tailor messages to address access barriers specific to low-income populations. Subsidies, incentives, and food assistance programs can help make nutrient-dense foods affordable in underserved communities, and education initiatives should highlight cost-effective ways to incorporate more produce into daily diets. Integrating these dietary interventions with broader health policies—such as diabetes screening and management programs, especially for older adults and those with low education—can amplify the impact. Additionally, promoting complementary health behaviors, such as exercise and reduced intake of processed foods, should be part of these initiatives. Targeted policies, including subsidized fresh produce and comprehensive health education across all income levels, can further address health disparities and empower individuals to make sustainable, preventive dietary changes.

5.2.1.5. Food Insecurity

The table 5.2.1.5.1. demonstrates a significant relationship between food insecurity and the prevalence of diabetes, with the severity of food insecurity showing a stepwise increase in the likelihood of diabetes. In the unadjusted model, individuals experiencing mild food insecurity ("WITHOUT HUNGER") have 15.46% higher odds of diabetes compared to those who are food secure ("SECURE"). This risk increases further for those experiencing moderate hunger ("W/MOD. HUNGER"), who have 41.16% higher odds, and for those facing severe hunger ("W/SEVERE HUNGER"), who exhibit an 18.58% increase in odds. This gradient indicates that even mild food insecurity can heighten the risk of diabetes, with moderate hunger having the strongest effect in the unadjusted model.

When adjusting for demographic, socioeconomic, and lifestyle factors such as age, income, education, alcohol consumption, and marital status, the pattern remains significant but the magnitude of the association increases. For individuals experiencing mild food insecurity, the adjusted odds of diabetes are 30.4% higher than those who are food secure. The risk rises to 41.78% for those with moderate hunger and peaks at 62.09% for individuals experiencing severe

hunger. These findings suggest that food insecurity, even when accounting for potential confounding factors, independently contributes to a greater likelihood of developing diabetes. Seligman et al. (2007) conducted a study using data from the National Health and Nutrition Examination Survey (NHANES) and found that food insecurity was associated with a significantly higher risk of diabetes. After adjusting for sociodemographic factors and physical activity, adults with severe food insecurity were more than twice as likely to have diabetes compared to those who were food secure.

The results highlight the dual burden of food insecurity and chronic disease, illustrating how lack of access to adequate nutrition may lead to unhealthy dietary patterns, including higher consumption of cheap, calorie-dense, nutrient-poor foods. This may exacerbate diabetes risk through mechanisms such as obesity, poor glycemic control, and stress-related metabolic changes. Furthermore, the increased odds of diabetes among individuals with severe hunger underscore the compounded effects of chronic nutritional deprivation. Addressing food insecurity could thus play a pivotal role in diabetes prevention strategies, particularly for vulnerable populations who face systemic barriers to accessing healthy, affordable food. These findings call for targeted interventions, such as food assistance programs and public health policies, to mitigate the health consequences of food insecurity.

5.2.2. High Blood Pressure

5.2.2.1. National

The regression analysis for high blood pressure explores the relationship between fruit and vegetable consumption and hypertension risk, alongside other influential demographic and socioeconomic variables. Table 5.2.2.1.1 provides the logistic regression results, detailing both univariate and multivariate model outcomes. This section examines whether moderate and high levels of fruit and vegetable intake contribute to reduced odds of high blood pressure, while also considering the independent effects of factors such as education, income, age, sex, and marital status. These results shed light on the potential role of dietary choices and broader social determinants in influencing hypertension risk across the Canadian population.

Table 5.2.2.1.1. Logistic Regression Results for Probability of High Blood Pressure (hbp)

	Model 1 (Univariate)	Model 2 (Multivariate)
Constant	-1.3385*** (0.0686)	-0.4761*** (0.0687)
Fruit and Vegetable Consumption (fru_veg_cat)		
Moderate Consumption	0.1227** (0.0498)	-0.0143 (0.0155)

High Consumption	-0.0784 (0.0623)	-0.1332*** (0.0253)
Education Indicators		Yes
Household Income		
Less than $15,000		-0.1958*** (0.0206)
$15,000-$29,999		-0.4174*** (0.0280)
$30,000-$49,999		-0.5579*** (0.0316)
$50,000-$79,999		-0.7967*** (0.0387)
$80,000 or more		-0.7788*** (0.0551)
Year Indicators		Yes
Age Indicators		Yes
Sex (Female)		-0.0622*** (0.0231)
Marital Status Indicators		Yes
Province Indicators		Yes
Pseudo R-squared	0.0011	0.1678
Observations	667,033	579,304

Standard errors are reported in parentheses.
Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01

Moderate fruit and vegetable consumption was initially found to be positively associated with high blood pressure risk in the univariate model (coefficient = 0.1227, p = 0.014). However, in the multivariate model, this association became non-significant and slightly negative (coefficient = -0.0143, p = 0.356). This shift suggests that the initial positive association observed for moderate fruit and vegetable intake may be attributed to the influence of other variables in the model, such as income and age.

High fruit and vegetable consumption, on the other hand, showed a consistent protective effect against high blood pressure in both models. In the univariate model, the coefficient was -0.0784 (p = 0.208), which was not statistically significant. However, in the multivariate model, high consumption was associated with a statistically significant reduction in high blood pressure risk, with a coefficient of -0.1332 (p = 0.000). This result indicates that when controlling for other factors, high fruit and vegetable intake reduces the odds of high blood pressure by approximately 13.3%, underscoring its protective effect. The Dietary Approaches to Stop Hypertension (DASH) trial, published by Appel et al. (1997) in the New England Journal of Medicine, demonstrated that a diet rich in fruits and vegetables significantly lowered blood pressure. The study found that a diet high in fruits, vegetables, and low-fat dairy products reduced systolic blood pressure by 5.5 mmHg and diastolic blood pressure by 3.0 mmHg more than a control diet.

Education level also showed varying associations with high blood pressure. For instance, secondary education was associated with a slight increase in high blood pressure risk, with a coefficient of 0.0394 ($p = 0.032$). This finding suggests that individuals with a secondary education may have slightly higher odds of high blood pressure compared to those with less education. Conversely, individuals with other post-secondary education showed a significant protective effect, with a coefficient of -0.0773 ($p = 0.000$). Interestingly, the post-secondary graduate category did not show a significant association with high blood pressure risk in the multivariate model ($p = 0.990$).

Income level demonstrated a strong gradient effect, with higher income consistently associated with reduced odds of high blood pressure. For example, individuals earning between $50,000 and $79,999 had a coefficient of -0.7967 ($p = 0.000$), indicating substantially lower odds of high blood pressure compared to the lowest income group (under $15,000). This pattern suggests that higher income levels may afford access to resources or lifestyle factors that contribute to lower high blood pressure risk.

Age was another significant predictor, with younger individuals showing lower odds of high blood pressure compared to the reference group. Individuals aged 25 to 39 and 40 to 54 years had notably lower odds, while adults aged 70 years or more exhibited significantly higher odds, with a coefficient of 0.6666 ($p = 0.000$). This pattern emphasizes the well-documented link between aging and increased risk of high blood pressure.

Sex differences were also evident, as being female was associated with a slight reduction in high blood pressure risk (coefficient = -0.0622, $p = 0.007$), aligning with research that suggests women may have a lower prevalence of high blood pressure than men.

Marital status was found to be a significant factor, particularly for single individuals, who had substantially reduced odds of high blood pressure (coefficient = -1.0784, $p = 0.000$) compared to married individuals. This association may reflect lifestyle differences or health-related factors tied to marital status. Furthermore, being in a common-law relationship was associated with lower odds of high blood pressure, while individuals who were widowed, separated, or divorced showed a slight increase in risk.

In summary, these results highlight that high fruit and vegetable consumption, higher income, and younger age are consistently associated with reduced odds of high blood pressure. By contrast, factors such as male sex, and older age increase the risk. The change in significance

of moderate fruit and vegetable consumption from the univariate to the multivariate model suggests that the protective effect of high fruit and vegetable intake on high blood pressure is more pronounced when accounting for other socioeconomic, demographic, and lifestyle factors. The findings of my study align with those reported by Madsen, Sen, and Aune (2023), who demonstrated that a high intake of fruits and vegetables, as well as total fruit consumption, is associated with a reduced risk of hypertension. Their systematic review and meta-analysis of prospective studies, published in the *European Journal of Nutrition*, further supports the notion that dietary choices play a significant role in mitigating chronic disease risk, consistent with the results observed in my analysis.

5.2.2.2. Provincial

The relationship between fruit and vegetable consumption and high blood pressure (HBP) demonstrates considerable variability across provinces and specific food types. This discussion highlights the most significant findings, explores the role of control variables, and emphasizes provinces with notable results where high fruit and vegetable consumption demonstrates a protective effect.

In British Columbia, the base model revealed no significant association between aggregate fruit and vegetable consumption and HBP risk. Moderate consumption showed a non-significant 12.98% increase in odds, while high consumption reduced HBP odds by only 4.8% ($p > 0.05$). However, when controlling for demographic and socioeconomic factors—including income, education, age, marital status, and alcohol consumption—the protective effects of higher fruit and vegetable intake became evident. Moderate consumption was associated with a significant 10.9% reduction in HBP odds (OR = 0.89). High consumption demonstrated a 23.4% reduction in odds (OR = 0.77, $p < 0.05$).

The disaggregated model further highlighted the differential effects of specific food types. Fruit juice emerged as a protective factor, reducing HBP odds by 11.1% ($p < 0.001$). Non-starchy vegetables also demonstrated significant benefits, while potatoes were linked to a 39.7% increase in odds ($p < 0.001$). These results suggest that the protective effect of high fruit and vegetable consumption is primarily driven by specific types like fruit juice and non-starchy vegetables, while starchy vegetables like potatoes may negate some benefits.

Quebec provided compelling evidence of the benefits of high fruit and vegetable consumption. In the base model, high consumption was associated with a 19.1% reduction in HBP odds (OR = 0.79, $p < 0.001$). After adjusting for covariates, including age, sex, income, education, and alcohol use, this protective effect remained significant but attenuated to a 13.41% reduction (OR = 0.86, $p < 0.001$). Higher income consistently reduced HBP odds, reflecting better access to health resources and healthier dietary habits among wealthier individuals.

The disaggregated analysis revealed that fruit juice reduced HBP odds by 6.6% ($p < 0.001$), likely due to its high potassium and antioxidant content. Potatoes increased HBP odds by 7.8% ($p < 0.001$), reinforcing concerns about the glycemic impact of starchy vegetables.

These results suggest that while high aggregate consumption is beneficial, targeted recommendations focusing on low-glycemic, nutrient-rich foods like fruit juice and leafy greens may enhance cardiovascular health.

In Alberta, the base model showed no significant effects of moderate or high fruit and vegetable consumption on HBP risk. However, after adjusting for demographic and lifestyle factors, high consumption became significantly protective, reducing HBP odds by 18% ($p = 0.008$). Moderate consumption remained non-significant, suggesting that only substantial increases in intake confer protective effects.

Disaggregated analysis confirmed the protective role of fruit juice and non-starchy vegetables, while potatoes were associated with an increased risk of HBP. These findings emphasize the conditional benefits of high fruit and vegetable consumption, which become apparent only under favorable demographic and socioeconomic conditions.

Table 5.2.2.2.1. Logistic Regression Results for Probability of High Blood Pressure in Quebec

	Model 1	**Model 2**
Constant	-1.294*** (-31.13)	-0.971*** (-15.39)
Fruit and Vegetable Consumption (fru_veg_cat)		
Moderate Consumption	-0.001 (0.05)	-0.013 (-0.88)
High Consumption	-0.212*** (-5.90)	-0.144*** (-5.59)
Education Indicators		Yes
Household Income Indicators		Yes
Year Indicators		Yes
Age Indicators		Yes
Sex Indicators		Yes
Marital Status Indicators		Yes
Observations	111510	106366

Standard errors are reported in parentheses.
Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01

In Nova Scotia, the base model showed that moderate fruit and vegetable consumption was associated with a 7% increase in HBP odds (OR = 1.07, $p < 0.05$), while high consumption significantly reduced odds by 11% (OR = 0.89, $p < 0.01$). After adjusting for covariates, the protective effect of high consumption remained significant, with a 14% reduction in odds ($p < 0.01$). These results highlight the importance of sufficient intake levels for reducing HBP risk.
In the specific food model, fruit juice reduced HBP odds by 11% ($p < 0.01$) and potatoes increased odds by 43% ($p < 0.001$), underscoring the potential adverse effects of starchy vegetables.

In Prince Edward Island (PEI), moderate fruit and vegetable consumption was initially associated with a 24.7% increase in HBP odds ($p < 0.01$), which became non-significant after adjusting for socioeconomic and demographic factors. High consumption showed no significant protective effect in either model.

Income and education were pivotal in reducing HBP risk. For example, individuals earning above $80,000 experienced a 57.5% reduction in odds (OR = 0.425). Disaggregated analysis showed that potato consumption increased HBP odds by 34.6% (OR = 1.346) and general vegetable consumption reduced odds by 16.8% (OR = 0.832), reinforcing the benefits of non-starchy vegetables.

Across provinces, control variables such as income, education, age, and alcohol consumption consistently influenced the relationship between fruit and vegetable consumption and HBP.

Higher income levels were associated with lower HBP odds, likely reflecting better dietary quality and healthcare access and education emerged as a protective factor, particularly in provinces like Quebec and PEI, suggesting that knowledge and awareness of healthy eating patterns play a critical role.

The effects of fruit and vegetable consumption on high blood pressure risk vary significantly by province, intake level, and food type. British Columbia and Quebec stand out as provinces where high aggregate consumption consistently reduced HBP odds in adjusted models, while disaggregated analyses highlighted the protective roles of fruit juice and non-starchy vegetables. Conversely, potatoes consistently emerged as a risk factor across regions, suggesting

that starchy vegetables may counteract the benefits of other produce types. Previous studies indicate that a high intake of fruits and vegetables combined, as well as total fruit consumption, was associated with a reduced risk of hypertension, although the findings for specific fruit and vegetable subtypes were mixed and require further investigation (Madsen et al., 2023).

These findings underscore the importance of tailoring dietary recommendations to emphasize specific nutrient-dense, low-glycemic foods like fruit juice and leafy greens, while minimizing starchy and high-glycemic options like potatoes. Additionally, addressing socioeconomic disparities through education and income-focused interventions could amplify the protective effects of healthy dietary patterns on cardiovascular health.

5.2.2.3. Age

The relationship between fruit and vegetable consumption and high blood pressure (HBP) varies across age groups. In the 12–24 age group, unadjusted models showed moderate consumption associated with a 54.5% higher odds of HBP and high consumption with a 14.9% increase, both significant, possibly reflecting confounding factors or reverse causality. Adjusted results showed minimal effects, with moderate consumption increasing odds by 4.7% and high consumption reducing odds by 3.9%, neither significant. Among individuals aged 25–39, unadjusted models indicated a protective effect, with moderate and high consumption reducing odds by 15.4% and 27.5%, respectively, retaining significance in adjusted models with reductions of 12.8% and 23.4%. The Seguimiento Universidad de Navarra (SUN) Study found that higher fruit and vegetable consumption was inversely associated with blood pressure levels (Alonso et al., 2004). This aligns with the overall findings, especially for age groups 25 and above, where results reported protective effects of moderate and high fruit and vegetable consumption on high blood pressure.

For those aged 40–54, both unadjusted and adjusted models consistently showed significant protective effects, with high consumption reducing odds by 27.9% unadjusted and 24.4% adjusted, highlighting the cumulative cardiovascular benefits of healthy eating. In the 55–69 group, unadjusted models found moderate consumption reducing odds by 5.0% (not significant) and high consumption by 16.2% (significant), with adjusted models showing reductions of 4.5% and 14.0%, both significant. Finally, in the 70+ group, unadjusted models showed no significant association for moderate consumption (+0.3%) and a 9.4% reduction for high consumption (significant), while adjusted models showed reductions of 2.4% (not

significant) and 13.1% (significant), reflecting smaller yet consistent protective effects in older adults, possibly due to diminished physiological responsiveness or competing risk factors.

The discussion highlights significant age-dependent variations in the relationship between fruit and vegetable consumption and high blood pressure (HBP). Protective effects are strongest among younger and middle-aged adults, particularly with high consumption, while benefits diminish in older adults, likely due to metabolic changes, accumulated cardiovascular damage, and comorbidities. High consumption consistently outperformed moderate consumption in reducing HBP odds, supporting public health recommendations for higher intake levels to achieve cardiovascular benefits. Adjusted models suggest that these effects are not merely confounded by demographic factors but reflect genuine dietary advantages. These findings underscore the importance of promoting fruit and vegetable consumption across all age groups, with tailored interventions to establish lifelong healthy eating habits in younger individuals and to mitigate HBP risk in older adults. The conclusion emphasizes the need for targeted dietary guidelines and further research to understand age-related differences and the long-term effects of dietary interventions on cardiovascular health.

5.2.2.4. Income

The analysis reveals significant variations in the effects of fruit and vegetable consumption on high blood pressure (HBP) across income groups and after accounting for covariates. Before adjustments, moderate and high consumption were generally associated with increased odds of HBP across income groups, with increases ranging from 19.5% (moderate consumption in the $30,000–$49,999 group) to 12.8% (high consumption in the no-income group). After adjusting for covariates, high consumption consistently showed a protective effect, reducing HBP odds by 16.0% in the $30,000–$49,999 group, 19.4% in the $50,000–$79,999 group, and 10.9% in the $80,000 or more group. Moderate consumption had smaller or non-significant effects after adjustments, particularly in higher income groups, where high consumption provided more pronounced benefits. Covariates such as age, education, alcohol use, and marital status significantly influenced HBP risk, with older age, lower education, and single marital status associated with higher odds. These findings highlight the greater cardiovascular benefits of high fruit and vegetable consumption, particularly for lower-income groups, and emphasize the importance of addressing demographic and lifestyle factors in public health interventions.

The relationship between fruit and vegetable consumption and high blood pressure (HBP) varies significantly across income groups. In low-income groups (e.g., no income, <$15,000, $15,000–$29,999), unadjusted models show increased odds of HBP with moderate and high consumption, likely reflecting confounding factors such as older age, existing health conditions, and limited healthcare access. For example, in the "No Income" group, moderate consumption increased HBP odds by 26.5%, and high consumption by 12.8%. After adjustments, these associations become neutral or weakly protective, with high consumption reducing HBP odds by 10% in the "Less than $15,000" group. Middle-income groups ($30,000–$49,999 and $50,000–$79,999) demonstrate strong protective effects of high consumption, reducing HBP odds by 16% to 20%, supported by better access to healthcare and balanced diets. In high-income groups ($80,000 or more), protective effects persist but are less pronounced (e.g., a 10.9% reduction with high consumption), possibly due to diminishing returns from already healthy lifestyles or substitution with other health-promoting foods. These findings underscore the influence of socioeconomic factors on dietary impact and highlight the need for targeted interventions to address disparities in access to nutrition and healthcare.

The implications of this analysis highlight the need for tailored public health strategies to address disparities in the relationship between fruit and vegetable consumption and high blood pressure (HBP) across income groups. For low-income groups, targeted interventions should focus on improving access to and education about high-quality, nutrient-dense produce, potentially through subsidies or food assistance programs. For middle-income groups, public health campaigns emphasizing the cardiovascular benefits of fruit and vegetable consumption can sustain and amplify protective effects. In high-income groups, promoting holistic dietary approaches that integrate fruit and vegetable intake with other health-promoting behaviors is essential. Future research should examine the quality and diversity of produce consumed across income levels to understand variations in outcomes and explore causal relationships through longitudinal studies. Public health initiatives should consider socioeconomic contexts when crafting dietary guidelines, recognizing that the effectiveness of interventions depends on addressing broader social determinants of health. These efforts can help lower-income groups overcome barriers to healthy eating and reinforce balanced dietary habits in middle- and high-income groups, maximizing the public health benefits of increased fruit and vegetable consumption.

5.2.2.5. Food Insecurity

The logistic regression analysis reveals complex relationships between food insecurity and high blood pressure (HBP). The results are shown in the table 5.2.1.5.1. In the unadjusted model, food insecurity is negatively associated with the likelihood of reporting HBP across all food insecurity categories. Specifically, individuals categorized as WITHOUT HUNGER have 26.7% lower odds of having HBP compared to those who are food secure (SECURE), while those experiencing MODERATE HUNGER show a non-significant reduction in odds (8.3% lower odds, $p = 0.074$). However, individuals experiencing SEVERE HUNGER exhibit a significant 31.3% lower odds of reporting HBP compared to the SECURE group.

When controlling for demographic, socioeconomic, and lifestyle factors in the second model, the results differ substantially. The association between food insecurity and HBP weakens, and the patterns change. For individuals in the WITHOUT HUNGER category, the adjusted odds of HBP are no longer significant. However, those experiencing MODERATE HUNGER have 13.1% higher odds of reporting HBP compared to the SECURE group, and this result is statistically significant ($p < 0.001$). Notably, for individuals in the SEVERE HUNGER category, the association becomes insignificant, suggesting that the initial negative association observed in the unadjusted model may be confounded by other variables.

These findings highlight the nuanced relationship between food insecurity and HBP. The initial protective effect observed in the unadjusted model may reflect complex biases in the reporting or diagnosis of HBP among food-insecure populations, potentially due to differences in healthcare access or health-seeking behaviors. After adjusting for confounders, moderate hunger appears to increase the risk of HBP, possibly due to the physiological stress and poor dietary patterns associated with food insecurity. The insignificant findings for severe hunger in the adjusted model may result from limited statistical power or competing health risks that overshadow the direct effects on HBP.

Additionally, the covariates provide important insights. Age has a significant positive association with HBP for older age groups, consistent with known age-related increases in blood pressure. Lower income levels and certain marital statuses (e.g., single or widowed) are associated with reduced odds of HBP, potentially reflecting selection effects in health status within these groups. These findings emphasize the importance of addressing the broader social determinants of health when evaluating the impact of food insecurity on chronic conditions like

HBP. The results align with a study done by Townsend et al. (2023) who conducted a cross-sectional study using data from 124 participants in the USDA-funded Children's Healthy Living Center of Excellence study. They used Self-reported questionnaires to assess demographics, physical activity, diet, food insecurity, and financial instability, while biometric measurements (blood pressure, weight, height) were collected. Hierarchical linear regression was used to analyze the effects of these variables on systolic blood pressure, controlling for confounders such as BMI and dietary intake. The study identified a significant independent association between food insecurity and elevated systolic blood pressure in a multiethnic population.

The analysis underscores the importance of considering confounding factors and the heterogeneity within food-insecure populations. Targeted interventions focusing on mitigating the stress and dietary inadequacies associated with moderate food insecurity could help reduce the burden of HBP. Future research should explore the pathways linking food insecurity to HBP, particularly focusing on healthcare access, dietary quality, and stress-related mechanisms.

5.2.3. Heart Diseases

5.2.3.1. National

Heart disease is a major health concern, influenced by various lifestyle and socioeconomic factors. While fruit and vegetable consumption is widely believed to benefit cardiovascular health, its precise impact on heart disease risk remains complex, especially when considering factors like age, income, and education.

This section examines the association between fruit and vegetable intake and heart disease risk in the Canadian population, using univariate and multivariate logistic regression models. By controlling for demographic and socioeconomic variables, we aim to isolate the independent effect of fruit and vegetable consumption on heart disease. Key findings and implications for public health are detailed in the following analysis.

Table 5.2.3.1.1 presents the logistic regression results for the probability of heart disease, highlighting the influence of fruit and vegetable consumption alongside other demographic and socioeconomic factors.

In the univariate model, moderate fruit and vegetable consumption was associated with an increased risk of heart disease (coefficient = 0.0762, p = 0.004). However, in the multivariate model, this association became non-significant (coefficient = -0.0029, p = 0.829), suggesting that

the initial positive association may be explained by confounding factors such as income and age, which were accounted for in the multivariate model.

High fruit and vegetable consumption, on the other hand, showed a significant protective effect against heart disease in both models. In the univariate model, the coefficient was -0.1226 ($p = 0.001$), while in the multivariate model, high consumption remained significantly associated with reduced odds of heart disease (coefficient = -0.0610, $p = 0.003$). The odds ratio in the multivariate model indicates that high fruit and vegetable intake is associated with a 6.1% reduction in heart disease risk, underscoring its protective role even when controlling for other variables. A Jordanian Case-Control Study investigated the relationship between fruit and vegetable consumption and cardiovascular diseases (CVD) in Jordan. The results strongly support the protective effect of fruit and vegetable intake against heart disease. Consuming 3 servings of vegetables per day significantly decreased the risk of CVD by about 54% (Tayyem et al., 2020).

Education level showed mixed associations with heart disease risk. Individuals with post-secondary education had slightly higher odds of heart disease (coefficient = 0.0690, $p = 0.010$). This somewhat unexpected finding may point to unobserved factors or health behaviors not fully captured in the model. Other education levels did not show significant associations with heart disease, suggesting that post-secondary education may have unique influences on heart disease risk.

Income level demonstrated a strong protective gradient against heart disease, with higher incomes associated with lower risk. For instance, individuals earning between $50,000 and $79,999 had a coefficient of -1.0135 ($p = 0.000$), indicating substantially lower odds of heart disease compared to those earning below $15,000. This trend suggests that higher income may provide access to healthcare, healthier dietary options, and resources that collectively lower heart disease risk.

Age was another significant predictor of heart disease risk. Compared to individuals under 25, all age groups showed significantly lower odds of heart disease, except for those aged 70 and above, where the association was not significant. The 25-39 age group, in particular, had a coefficient of -2.7937 ($p = 0.000$), indicating markedly lower odds of heart disease compared to younger individuals. This age-related pattern may reflect cohort-specific health advantages or lifestyle factors that protect against heart disease.

Sex differences were also observed, with female individuals showing a lower risk of heart disease compared to males. The coefficient for being female was -0.5841 (p = 0.000), suggesting a significantly reduced risk. This finding aligns with previous research indicating lower heart disease prevalence among women, possibly due to biological or lifestyle factors (Betai et al., 2024).

Marital status showed notable associations with heart disease risk. Being single was linked to a substantial reduction in heart disease odds (coefficient = -1.3715, p = 0.000), possibly reflecting differences in health behaviors or social factors between single and married individuals. Additionally, those in common-law relationships also had lower odds of heart disease (coefficient = -0.1451, p = 0.002), further indicating the potential impact of relationship status on heart health.

In summary, these findings indicate that high fruit and vegetable consumption, higher income, younger age, and being female are associated with lower odds of heart disease. Conversely, factors such as abstaining from alcohol and certain marital statuses appear to increase heart disease risk. The shift in the significance of fruit and vegetable consumption from the univariate to the multivariate model suggests that the protective effect of high fruit and vegetable intake is influenced by other socioeconomic and demographic factors, reinforcing the importance of a comprehensive approach when examining dietary impacts on heart disease risk.

5.2.3.2. Provincial

The analysis of fruit and vegetable consumption's impact on heart disease reveals diverse outcomes across Canadian provinces, highlighting the importance of specific produce types, intake levels, and socioeconomic factors. This discussion focuses on the most significant findings and control variables, with particular attention to provinces where fruit and vegetable consumption has demonstrated substantial effects on heart disease risk.

In British Columbia, the base model showed a slight but significant increase in heart disease odds for moderate fruit and vegetable consumption (OR = 1.08, p = 0.043), while high consumption was non-significant (OR = 0.93, p = 0.341). After controlling for demographic and socioeconomic factors, including alcohol use, income, education, age, sex, and marital status, both moderate and high consumption became non-significant. These findings suggest that other lifestyle factors may explain much of the variation in heart disease risk, diminishing the independent effect of general fruit and vegetable consumption. The disaggregated model

revealed critical nuances. General vegetables reduced heart disease odds by 15.4% (OR = 0.85, $p < 0.001$), emphasizing their protective role while potatoes and carrots increased heart disease odds, highlighting the adverse effects of starchy vegetables on cardiovascular health.

These results demonstrate the need to differentiate between produce types when assessing the impact of diet on heart disease, as starchy vegetables may obscure the protective benefits of nutrient-rich options like leafy greens.

Quebec consistently demonstrated the benefits of high fruit and vegetable consumption. In the base model, high consumption reduced heart disease odds by 35% (OR = 0.65, $p < 0.001$). After adjusting for key covariates such as income, education, age, and alcohol use, this effect remained significant, though reduced, with a 15% reduction in odds (OR = 0.85, $p < 0.001$). Moderate consumption showed a smaller, non-significant protective effect.

Table 5.2.3.2.1. Logistic Regression Results for Probability of Heart Disease in Quebec

	Model 1	**Model 2**
Constant	-2.506*** (-52.62)	-1.105*** (-12.40)
Fruit and Vegetable Consumption (fru_veg_cat)		
Moderate Consumption	-0.127*** (-4.59)	-0.078** (-3.09)
High Consumption	-0.345*** (-7.37)	-0.153*** (-4.46)
Education Indicators		Yes
Household Income Indicators		Yes
Year Indicators		Yes
Age Indicators		Yes
Sex Indicators		Yes
Marital Status Indicators		Yes
Observations	111510	106366

Standard errors are reported in parentheses.
Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01

Key control variables revealed additional insights. Higher income levels significantly reduced heart disease odds, with wealthier individuals experiencing better cardiovascular outcomes due to improved dietary quality and healthcare access. Disaggregated analysis highlighted the protective role of fruit juice, which reduced odds by 3.6% (OR = 0.96, $p < 0.05$) and non-starchy vegetables, which consistently lowered risk. In contrast, potatoes were associated with a 6.5% increase in odds, underscoring the risks posed by starchy vegetables.

These findings reinforce the importance of promoting non-starchy, nutrient-dense vegetables while limiting high-glycemic options for heart disease prevention.

In Alberta, the base model showed a dual effect. Moderate consumption increased heart disease risk by 13% (p = 0.014), while high consumption reduced it (p = 0.007). After controlling for demographic and lifestyle covariates, high consumption retained its protective effect, suggesting that substantial intake levels are necessary to achieve cardiovascular benefits. Specific food analysis provided further clarity. Vegetables consistently reduced heart disease odds, while potatoes and carrots increased risk, highlighting the need to limit starchy vegetable intake. Fruits unexpectedly showed a positive association with heart disease risk in some models, which may reflect the influence of sugary or processed fruit products.

These results suggest that high fruit and vegetable consumption can offer protection against heart disease, but the type of produce consumed is crucial. Recommendations should prioritize leafy greens and non-starchy vegetables while advising moderation of starchy and sugary items.

In the territories of Yukon, Nunavut, and NWT, high fruit and vegetable consumption was significantly associated with reduced heart disease risk. This aligns with established research linking the fiber, antioxidants, and vitamins in produce to improved cardiovascular outcomes through mechanisms such as reduced inflammation and oxidative stress.

Table 5.2.3.2.2. Logistic Regression Results for Probability of Heart Disease in Alberta

	Model 1	**Model 2**
Constant	-2.942*** (-36.76)	-1.509*** (-13.11)
Fruit and Vegetable Consumption (fru_veg_cat)		
Moderate Consumption	0.131* (-2.47)	0.045 (-1.41)
High Consumption	-0.179** (-2.69)	-0.125** (-2.58)
Education Indicators		Yes
Household Income Indicators		Yes
Year Indicators		Yes
Age Indicators		Yes
Sex Indicators		Yes
Marital Status Indicators		Yes
Observations	74203	60969

Standard errors are reported in parentheses.
Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01

Disaggregated findings revealed that fruits and leafy green vegetables offered strong protective effects, emphasizing the role of nutrient-dense options in heart disease prevention.

Potatoes, however, increased heart disease odds, likely due to their high glycemic load and potential to elevate blood pressure and cholesterol levels. These results highlight the value of focusing on low-glycemic, non-starchy vegetables in dietary recommendations for heart disease prevention in northern populations.

In Manitoba, moderate fruit and vegetable consumption was associated with increased heart disease risk ($p < 0.01$), suggesting that intake below a certain threshold may not provide cardiovascular benefits. High consumption, while not significant, showed a trend toward risk reduction.

Specific food analysis revealed that vegetables significantly reduced heart disease odds ($p < 0.001$), likely due to their fiber, vitamins, and phytonutrient content, which contribute to lower cholesterol and reduced inflammation. Potatoes increased odds ($p < 0.001$), with the risk likely exacerbated by their consumption in fried or processed forms. These findings reinforce the need to focus on nutrient-rich, non-starchy vegetables while limiting starchy items, particularly when consumed in less healthy preparations.

In Newfoundland, high fruit and vegetable consumption significantly reduced heart disease risk (Coef. = -0.26, $p < 0.001$), while moderate consumption was non-significant. These results suggest that sufficient intake levels are necessary to achieve cardiovascular benefits.

Disaggregated analysis highlighted that general vegetables reduced heart disease odds by 20% (Coef. = -0.20, $p < 0.001$), emphasizing their protective role while potatoes and carrots, in contrast, increased odds, underscoring the risks associated with starchy vegetables. Potato consumption increased the odds of having heart diseases by 32.5%. These findings suggest that while high overall intake is beneficial, focusing on non-starchy vegetables is critical for maximizing cardiovascular health benefits.

Across provinces, control variables such as income, education, and sex consistently influence heart disease outcomes. Higher income levels were protective across most provinces, reflecting the benefits of better dietary quality, healthcare access, and healthier lifestyles. Education emerged as a significant protective factor, likely due to its role in promoting awareness of healthy eating habits. Females consistently showed lower heart disease odds compared to males, reflecting gender differences in cardiovascular risk and protective factors.

The relationship between fruit and vegetable consumption and heart disease varies significantly depending on intake levels, specific food types, and socioeconomic factors.

Provinces such as Quebec, Newfoundland, and the Yukon/Nunavut/NWT territories showed strong protective effects of high fruit and vegetable consumption, particularly for non-starchy vegetables and fruit juice. Conversely, starchy vegetables like potatoes and carrots consistently increased heart disease risk, emphasizing the need for nuanced dietary recommendations.

A meta-analysis of cohort studies of the relationship between ischaemic heart disease and markers of fruit and vegetable consumption revealed that the risk of ischaemic heart disease is about 15% lower for high consumption of fruits and vegetables.These results align closely with the regression results of this study (Law & Morris, 1998).

Future public health strategies should prioritize promoting non-starchy, nutrient-dense vegetables and minimizing high-glycemic, starchy foods to optimize cardiovascular health. Additionally, addressing socioeconomic disparities through education and income-focused interventions could amplify the benefits of healthy dietary patterns in reducing heart disease risk.

5.2.3.3. Age

This analysis highlights age-specific patterns in the relationship between fruit and vegetable consumption and heart disease risk. In younger adults (12–39 years), dietary factors show limited impact, with moderate and high consumption either insignificant or marginally associated with heart disease due to low baseline risk and confounding socioeconomic factors. For middle-aged adults (40–54 years), unadjusted models suggest protective effects, with odds reductions of approximately 19.8% for moderate and 19.7% for high consumption, though these effects become insignificant after adjustment, emphasizing the influence of confounders like income and lifestyle. In older adults (55+ years), high consumption consistently shows significant protective effects, reducing odds of heart disease by up to 23.6% in unadjusted models and retaining significance in adjusted models, particularly in the 70+ age group, where high consumption reduces odds by 9.3%. These findings underscore the cumulative benefits of lifelong dietary habits, the stronger protective effects of high consumption compared to moderate intake, and the need for tailored dietary interventions to address cardiovascular risk at different life stages.

A comparative analysis across age groups reveals that the protective effects of fruit and vegetable consumption on heart disease risk increase with age. In younger populations (12–39 years), no consistent protective effects are observed, likely due to the low baseline risk of heart disease and the overshadowing influence of genetic and lifestyle factors. In middle-aged adults

(40–54 years), unadjusted models indicate significant reductions in heart disease odds with both moderate and high consumption, reflecting the growing impact of dietary patterns on cardiovascular health during this period. However, these effects diminish in adjusted models, underscoring the role of socioeconomic and lifestyle factors as confounders. In older adults (55+ years), high consumption consistently demonstrates stronger protective effects than moderate consumption, with significant reductions in heart disease odds, particularly in the 70+ group, where cumulative benefits of lifelong healthy eating are evident. Adjusted models reveal that high consumption provides independent cardiovascular benefits despite attenuation by confounders, emphasizing the importance of promoting higher intake thresholds to maximize heart health benefits across all age groups.

For Younger Adults (12–39 Years), Public health initiatives should focus on establishing lifelong healthy eating habits, emphasizing the long-term cardiovascular benefits of fruit and vegetable consumption despite limited immediate effects. Educational campaigns in schools, universities, and community programs can help instill these behaviors early, setting the foundation for future heart health. The group Middle-Aged Adults (40–54 Years) represents a critical window for interventions, as cardiovascular risks begin to emerge. Public health strategies should promote transitioning from moderate to high fruit and vegetable consumption levels through workplace wellness programs, family-focused initiatives, and accessible community resources. These efforts can mitigate rising heart disease risks effectively. For Older Adults (55+ Years), Policies should prioritize improving access to fresh fruits and vegetables for seniors, particularly those with limited mobility or on fixed incomes. Interventions should integrate dietary recommendations into chronic disease management programs to enhance cardiovascular health outcomes. In adults aged 70+, the emphasis should be on maintaining high consumption levels to leverage cumulative dietary benefits.

The protective effects of fruit and vegetable consumption on heart disease vary across age groups, becoming more pronounced with age and higher intake levels. While younger adults show limited immediate benefits, middle-aged and older adults experience significant protective effects, particularly from high consumption. These findings highlight the importance of lifelong adherence to dietary guidelines and the need for tailored public health interventions to promote heart health across the lifespan. Future research should explore the biological mechanisms,

long-term impacts of dietary patterns, and the interplay with other lifestyle factors to refine and target interventions effectively.

5.2.3.4. Income

The relationship between fruit and vegetable consumption and heart disease varies notably across income groups, with significant differences between unadjusted and adjusted models. In lower-income groups (e.g., no income, <$15,000, $15,000–$29,999), unadjusted models show moderate consumption generally increasing odds of heart disease (e.g., 17.9% increase for "No Income"), while high consumption has minimal or borderline significant protective effects. After adjustments, high consumption reduces odds in some cases, such as a 9.9% reduction in the "No Income" group ($p=0.007$) and a 7.7% reduction in the $15,000–$29,999 group ($p=0.022$), indicating potential dietary benefits when confounding factors are controlled. In middle-income groups ($30,000–$49,999 and $50,000–$79,999), moderate consumption continues to show mixed effects, with slight increases or reductions in odds that are not statistically significant after adjustments. High consumption in these groups demonstrates modest protective trends, such as a 14.1% reduction in unadjusted odds for the $50,000–$79,999 group, though significance is not consistent. For high-income groups ($80,000 or more), moderate consumption unexpectedly increases odds in both unadjusted (7.1%) and adjusted models (11.1%, $p<0.001$), while high consumption shows a borderline significant reduction in unadjusted odds (17.9%) but loses significance after adjustments. These findings underscore the complexity of the relationship between diet and heart disease, influenced by socioeconomic factors and confounders such as access to healthcare, quality of diet, and lifestyle habits.

The relationship between fruit and vegetable consumption and heart disease varies significantly across income groups, with notable differences in the effects of moderate and high consumption. In lower-income groups (e.g., no income or less than $15,000), moderate consumption inconsistently increases odds of heart disease in unadjusted models, likely due to confounding factors such as limited healthcare access or food insecurity. After adjusting for these confounders, moderate consumption generally shows slight protective effects or no significant impact. High consumption, however, consistently demonstrates a protective effect across income groups, with odds reductions ranging from 5.7% to 9.9% in adjusted models. The significance of these findings in adjusted models suggests that controlling for variables like education, alcohol

use, and marital status reveals the genuine benefits of high fruit and vegetable consumption. Mid-income groups ($30,000–$79,999) exhibit weaker effects, possibly due to confounding lifestyle factors or limited healthcare access, while higher-income groups ($80,000+) show a puzzling positive association between moderate consumption and heart disease risk, possibly reflecting dietary or lifestyle nuances.

A Mendelian randomization study found that genetically determined socioeconomic status may have an impact on vegetable intake. Specifically, raw vegetable intake was positively correlated with education attainment and household income. Socioeconomic status can limit access to fresh vegetables and fruits due to lack of health literacy and high prices (Huang et al., 2023).

These observations highlight important public health implications. Campaigns should emphasize high fruit and vegetable consumption across all income groups, particularly focusing on lower-income groups where benefits appear diminished due to barriers like affordability and access to high-quality produce. Policy interventions should address these structural challenges by subsidizing nutrient-rich fruits and vegetables and improving access to healthcare resources. Inconsistencies in moderate consumption effects, especially in higher-income groups, underscore the need for further research into factors like processed food intake, calorie-dense diets, and healthcare utilization. Tailored interventions can help ensure that low- and mid-income households achieve the full health benefits of improved dietary habits, while public health messaging should promote the importance of high fruit and vegetable consumption universally.

5.2.3.5. Food Insecurity

The table 5.2.1.5.1. presents regression results for the relationship between food insecurity and heart disease, with the severity of food insecurity correlating directly with the likelihood of developing heart disease. In the unadjusted model, individuals in the WITHOUT HUNGER category have 14.6% lower odds of heart disease compared to food-secure individuals. However, those experiencing W/MOD. HUNGER shows a non-significant increase in odds by 11.2%, while individuals in the W/SEVERE HUNGER category have a 46.8% higher likelihood of heart disease, a result that is statistically significant. These findings suggest that mild food insecurity may not significantly increase the risk, but severe hunger is strongly associated with heart disease, potentially due to the compounded effects of chronic stress, poor nutrition, and other socioeconomic challenges.

When adjusting for key demographic, socioeconomic, and lifestyle factors, the associations become stronger and more consistent, emphasizing the independent role of food insecurity in heart disease risk. Individuals in the WITHOUT HUNGER category show 13.5% higher odds of heart disease after adjustment, while those in the W/MOD. HUNGER and W/SEVERE HUNGER categories demonstrate significantly higher risks, with 40.5% and 78.8% higher odds, respectively. This gradient highlights the progressive impact of food insecurity on heart health, with the most severe levels posing the greatest risk. The adjusted results also indicate that the apparent protective effect seen in the unadjusted model for the WITHOUT HUNGER category may be due to confounding factors such as differences in healthcare access or underlying health behaviors.

The covariates further illuminate the broader context. Younger age groups (25–54 years) show significantly lower odds of heart disease, while older individuals (55 years and above) have higher risks, consistent with age-related vulnerability. Higher income levels are strongly protective, with individuals in the highest income bracket ($80,000 or more) showing a 92.5% lower likelihood of heart disease compared to the lowest income group. Females exhibit significantly lower odds of heart disease than males, while individuals abstaining from alcohol have higher odds, potentially reflecting abstention due to pre-existing conditions.

Berkowitz et al. (2017) analyzed data from the National Health and Nutrition Examination Survey (NHANES) from 2005 to 2012 to examine trends in food insecurity among adults with diet-sensitive cardiometabolic conditions, including diabetes, hypertension, coronary heart disease, congestive heart failure, and obesity. The study found that food insecurity rates doubled during the period, reaching 18.33% in 2011–2012, with significantly higher rates among individuals with cardiometabolic conditions compared to those without. The findings highlight the growing challenge of food insecurity and its implications for managing and preventing cardiometabolic diseases.

In conclusion, the findings underscore the critical impact of food insecurity, particularly at moderate and severe levels, on heart disease risk. Addressing food insecurity through targeted interventions—such as improving access to affordable, nutritious food and reducing stress related to economic hardship—could play a pivotal role in reducing the burden of heart disease. These results highlight the need for integrated public health strategies that address both nutritional and socioeconomic determinants of heart health.

5.2.4. Cancer

5.2.4.1. National

Cancer risk is shaped by a combination of lifestyle and socioeconomic factors, including diet. While fruit and vegetable intake is often associated with reduced cancer risk, its exact effect is uncertain when accounting for variables like age, income, and education. This section examines the association between fruit and vegetable consumption and cancer risk in Canada, using regression models to identify any protective effects while considering demographic influences.

Table 5.2.4.1.1 presents the logistic regression results for the probability of cancer, illustrating the associations between fruit and vegetable consumption and cancer risk, as well as the influence of various socioeconomic and demographic factors.

In the univariate model, moderate fruit and vegetable consumption was significantly associated with higher cancer odds (coefficient = 0.2031, $p < 0.001$). However, in the multivariate model, this association became non-significant (coefficient = 0.0234, $p = 0.186$), suggesting that the initial positive association may have been influenced by other factors such as education and income, which were controlled for in the multivariate analysis.

High fruit and vegetable consumption showed a small yet significant positive association with cancer risk in both models. In the univariate model, the coefficient was 0.1803 ($p = 0.003$), while in the multivariate model, it remained positive and significant with a coefficient of 0.0622 ($p < 0.001$). This result, which contrasts with the common understanding that higher fruit and vegetable intake reduces chronic disease risk, may indicate the presence of confounding factors not fully captured in this analysis. Further investigation could help clarify the relationship and identify potential underlying variables. In contrast to Wu et al., (2015), who reported a significant association between fruit and vegetable intake and reduced cancer risk, our study did not find a statistically significant effect in a similar context.

Education level showed a significant positive association with cancer risk in the multivariate model. The coefficients for secondary graduate, other post-secondary, and post-secondary graduate categories were 0.1320, 0.1629, and 0.2939, respectively. This finding suggests that individuals with higher education may have an increased likelihood of cancer, potentially due to lifestyle or occupational factors not directly accounted for in this model.

Income level, conversely, was strongly associated with a reduced likelihood of cancer. For instance, individuals earning between $50,000 and $79,999 had a coefficient of -0.6252 ($p < 0.001$), indicating significantly lower odds of cancer compared to those with incomes below $15,000. This trend underscores the protective role of higher income, which may facilitate better access to healthcare, early detection, and overall healthier living conditions, thereby reducing cancer risk.

Age emerged as a strong predictor of cancer risk, with younger age groups displaying significantly lower odds of cancer compared to older individuals. For example, the coefficient for individuals aged 25-39 was -2.5802 ($p < 0.001$) relative to the reference age group, highlighting the natural increase in cancer risk with age.

Sex differences in cancer risk were also observed, although not statistically significant in the adjusted model. Being female was associated with a lower risk of cancer (coefficient = -0.0950, $p = 0.179$), aligning with some studies but not reaching significance in this analysis.

Marital status showed a notable association with cancer risk, with single individuals exhibiting lower odds of cancer (coefficient = -1.0887, $p < 0.001$). This difference may reflect social or lifestyle variations across marital status groups, potentially influencing health behaviors and cancer risk.

In summary, these results underscore the significant role of age, income, and education in shaping cancer risk. Although high fruit and vegetable consumption showed a positive association with cancer in the multivariate model, this finding is likely influenced by unobserved lifestyle or health factors. Overall, the multivariate analysis provides a nuanced understanding of cancer risk, revealing how socioeconomic and demographic variables interplay to affect health outcomes.

5.2.4.2. Provincial

The relationship between fruit and vegetable consumption and cancer risk reveals a complex interplay of dietary patterns, specific food types, and socioeconomic factors. The analysis highlights that while aggregate fruit and vegetable intake often does not show consistent protective effects, certain produce types, particularly non-starchy vegetables, may play a significant role in reducing cancer risk. This discussion emphasizes the most important results, including notable provincial variations and the influence of control variables.

In British Columbia, the base model revealed that moderate fruit and vegetable consumption was significantly associated with an increased cancer risk (OR = 1.36, $p < 0.001$), while high consumption showed a non-significant increase (OR = 1.22, $p = 0.065$). After adjusting for age, income, education, marital status, and other demographic factors, moderate consumption remained significantly associated with higher cancer odds (OR = 1.14, $p = 0.028$), while high consumption became non-significant.

Disaggregated analysis shed light on these findings. Fruits increased cancer odds by 6.4% (OR = 1.06, $p = 0.002$), indicating that some fruit types may contribute to elevated cancer risk, potentially due to sugar content or preparation methods. Vegetables showed a protective effect, reducing cancer odds by 9.3% (OR = 0.91, $p = 0.010$), emphasizing their role in countering the risks associated with other foods. Potatoes were associated with a substantial increase in cancer risk (OR = 1.25, $p < 0.001$), likely due to carcinogenic compounds like acrylamide formed during high-temperature cooking methods such as frying or baking. These findings indicate that while aggregate fruit and vegetable intake may not consistently reduce cancer risk, specific types, particularly starchy vegetables, could contribute to increased risk.

Table 5.2.4.2.1. Logistic Regression Results for Probability of Cancer in British Columbia

	Model 1	**Model 2**
Constant	-3.938*** (-54.15)	-3.415*** (-17.53)
Fruit and Vegetable Consumption (fru_veg_cat)		
Moderate Consumption	0.307*** (4.02)	0.129* (2.19)
High Consumption	0.198 (1.84)	0.07 (0.88)
Education Indicators		Yes
Household Income Indicators		Yes
Year Indicators		Yes
Age Indicators		Yes
Sex Indicators		Yes
Marital Status Indicators		Yes
Observations	82270	66867

Standard errors are reported in parentheses.
Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01

Quebec exhibited the most promising results for high fruit and vegetable consumption. In the base model, high consumption reduced cancer odds by 9.4% (OR = 0.91, $p = 0.05$). However, this effect became non-significant in the multivariate model (OR = 0.96, $p > 0.05$) after adjusting for income, education, and marital status, suggesting that socioeconomic factors play a substantial role in modulating cancer risk.

The disaggregated model offered further insights. Protective Foods - Fruit juice and salads demonstrated protective effects, with fruit juice slightly reducing cancer odds (OR = 0.96, $p < 0.05$) and salads offering broader protective benefits through their rich content of folate, fiber, and antioxidants. Other vegetables, particularly leafy greens, were consistently associated with lower cancer odds, likely due to their role in reducing inflammation and oxidative stress. Risk Factors - Potatoes increased cancer odds by 12% (OR = 1.12, $p < 0.001$), aligning with findings that acrylamides formed during high-temperature cooking may elevate cancer risk. These results highlight Quebec as a province where high fruit and vegetable intake, combined with careful selection of specific types, offers potential cancer-preventive benefits.

In Yukon, Nunavut, and NWT, the aggregate model showed no significant relationship between fruit and vegetable consumption and cancer risk. However, disaggregated analysis provided valuable insights. Salad intake significantly reduced cancer odds, with leafy greens offering protection through their fiber, antioxidants, and folate content, which may support cellular repair and reduce inflammation. Potatoes were positively associated with cancer risk, likely due to acrylamide formation during frying or baking. These findings suggest that dietary recommendations in these regions should emphasize non-starchy vegetables and discourage high-temperature cooking of starchy foods to minimize exposure to potential carcinogens.

Table 5.2.4.2.2. Logistic Regression Results for Probability of Cancer in Quebec

	Model 1	**Model 2**
Constant	-3.748*** (-54.43)	-3.649*** (-54.29)
Fruit and Vegetable Consumption (fru_veg_cat)		
Moderate Consumption	-0.036* (-1.96)	-0.062** (-3.45)
High Consumption	-0.094* (-1.98)	-0.038 (-0.86)
Education Indicators		Yes
Household Income Indicators		Yes
Year Indicators		Yes
Age Indicators		Yes
Sex Indicators		Yes
Marital Status Indicators		Yes
Observations	111510	106366

Standard errors are reported in parentheses.
Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01

In Alberta, aggregate fruit and vegetable consumption did not show significant effects on cancer risk in either the base or multivariate models. However, the disaggregated model revealed nuanced results. Vegetables exhibited a marginally significant protective effect ($p = 0.056$) and

remained protective in the fully adjusted model, emphasizing their role in cancer prevention. Fruits and potatoes were associated with increased cancer risk, suggesting that starchy or sugary items may contribute to elevated odds. These findings highlight the importance of focusing on nutrient-rich, non-starchy vegetables in dietary guidelines for cancer prevention in Alberta.

In Newfoundland, the base model showed that moderate fruit and vegetable consumption was positively associated with cancer risk (Coef. = 0.23, $p = 0.008$), while high consumption was non-significant. Disaggregated analysis provided clarity. General vegetables significantly reduced cancer odds (Coef. = -0.10, $p = 0.02$), supporting their role in mitigating cancer risk through their high fiber and phytochemical content. Potatoes were linked to increased cancer odds (Coef. = 0.27, $p < 0.001$), reinforcing concerns about the carcinogenic potential of starchy vegetables when cooked at high temperatures.

In Manitoba, aggregate fruit and vegetable consumption did not show significant effects on cancer risk. However, disaggregated analysis revealed. Salad consumption was strongly protective ($p < 0.001$), with leafy greens providing benefits against oxidative stress and inflammation. Potatoes increased cancer odds ($p < 0.001$), highlighting their potential role in elevating cancer risk through acrylamide exposure.

These results emphasize the importance of consuming diverse, nutrient-rich vegetables and minimizing high-temperature preparation of starchy items to reduce cancer risk.

Control variables such as income, education, and age played a significant role in modulating cancer risk. Higher income levels were consistently associated with lower cancer odds, reflecting better access to healthcare, healthier dietary choices, and preventive care. Higher education levels often correlated with increased cancer odds, potentially due to higher cancer screening rates or greater awareness of symptoms, leading to more frequent diagnoses. Age was a critical factor, with older individuals showing higher cancer odds, reflecting the natural progression of cancer risk over time.

The effects of fruit and vegetable consumption on cancer risk are highly nuanced and depend on the specific types of produce consumed, preparation methods, and broader socioeconomic factors. Provinces such as Quebec, Newfoundland, and the Yukon/Nunavut/NWT territories demonstrated promising results for protective foods like leafy greens, salads, and vegetables, which consistently reduced cancer risk. Conversely, starchy vegetables like potatoes

emerged as significant risk factors, likely due to carcinogenic compounds formed during high-temperature cooking.

Key (2011) reviewed the association between fruit and vegetable consumption and cancer risk, finding limited or no significant protective effects for most cancers, except for moderate risk reduction in upper gastrointestinal cancers, which may be confounded by factors like smoking and alcohol. Similarly, my study yields mixed results, aligning with Key's conclusion that the relationship between fruit and vegetable intake and cancer risk remains inconclusive, particularly in well-nourished populations.

To maximize cancer prevention, public health strategies should emphasize increasing the intake of non-starchy, nutrient-dense vegetables while discouraging the consumption of starchy foods prepared at high temperatures. Addressing socioeconomic disparities through education and access to healthy foods will further amplify the protective effects of these dietary recommendations.

5.2.4.3. Age

This analysis highlights age-specific associations between fruit and vegetable consumption and cancer odds, revealing complex interactions influenced by dietary habits, lifestyle factors, and age-related risks. In younger adults (12–24 years), moderate consumption shows a significant 50.2% increase in cancer odds, while high consumption results in a smaller, nonsignificant 16.5% increase. These findings may be driven by confounding factors such as socioeconomic status, lifestyle habits, or dietary patterns that include processed or sugary fruits and vegetables. In the 25–39 age group, moderate consumption has no significant impact, while high consumption is associated with a 26.2% increase in odds, suggesting residual confounding or interactions with occupational or early-life risk factors. Among middle-aged adults (40–54 and 55–69 years), high consumption exhibits the most pronounced associations, with increases in cancer odds of 35.3% and 19.7%, respectively. These results persist even after adjustments, indicating potential links to dietary preparation methods, environmental exposures, or genetic predispositions. In older adults (70+ years), neither moderate nor high consumption demonstrates significant effects, possibly due to competing health risks, survivorship bias, or reduced sample sensitivity in this population.

These findings carry significant implications for public health strategies and dietary guidelines. For younger individuals, the unexpected associations with moderate consumption

suggest the need for a closer examination of overall diet composition and quality, as well as the potential influence of other lifestyle factors. For middle-aged groups, where high consumption correlates with increased cancer odds, research should explore the role of preparation methods, such as the use of pickled or fried vegetables, and potential dietary imbalances. In older adults, the absence of significant effects points to the importance of considering competing health risks and ensuring a balanced, nutrient-rich diet. Public health interventions should emphasize comprehensive approaches that address overall diet quality, preparation methods, and potential confounders such as lifestyle and socioeconomic status, while promoting fruit and vegetable consumption as part of a broader healthy dietary pattern tailored to each age group.

5.2.4.4. Income

The analysis reveals varying associations between fruit and vegetable consumption and cancer odds across income groups, with pronounced differences in unadjusted and adjusted models. In lower-income groups (<$30,000), unadjusted models indicate increased cancer odds with both moderate and high consumption, ranging from a 15.3% to 41.2% increase. These effects are attenuated but remain positive after adjustments, highlighting potential confounding factors like limited access to high-quality produce and disparities in healthcare. For example, the $15,000–$29,999 group shows adjusted risks of 13.8% (moderate consumption) and 15.9% (high consumption). These findings suggest a need to examine the impact of dietary quality and healthcare access on cancer risk within these groups.

Middle-income groups ($30,000–$79,999) show modest increases in cancer risk in unadjusted models, with moderate consumption raising odds by up to 28.8% and high consumption by 32.1%. However, adjusted models largely nullify these associations, reflecting the mitigating effects of better access to healthcare and higher dietary quality. High-income groups ($80,000+) display no significant associations, even in unadjusted models, likely due to consistent access to high-quality produce and healthcare resources, which buffer dietary risks. These findings emphasize the need for further research into produce quality and socioeconomic disparities and suggest targeted interventions to improve diet quality and healthcare access in lower-income populations.

The analysis reveals varying associations between fruit and vegetable consumption and cancer risk across the six income groups. Lower-income groups (No Income and <$15,000) exhibit increased odds of cancer with higher consumption, with moderate consumption raising

odds by 15-27% and high consumption by 9-26%, though these associations diminish after adjustments for confounders. Middle-income groups ($15,000–$49,999) consistently show significant unadjusted risk increases, with moderate and high consumption linked to 28-41% higher odds; however, adjustments reduce or nullify these effects, suggesting confounding factors. In higher-income groups ($50,000–$79,999 and $80,000+), unadjusted models show modest increases in cancer odds (20-23%), but these associations lose significance after adjustment, indicating the mitigating influence of access to healthcare, higher diet quality, and overall better living conditions. The findings underscore the interplay of socioeconomic factors, quality, and healthcare access in influencing dietary impacts on cancer risk. Larsen et al. (2020) conducted a Norwegian registry-based study linking data on education and income with cancer diagnoses from the Cancer Registry of Norway between 2012 and 2016. Using Poisson regression, they calculated incidence rate ratios (IRRs) for 23 cancer sites, confirming that cancer incidence rates vary across socioeconomic status levels. Similarly, my study observes disparities influenced by socioeconomic factors, aligning with Larsen et al.'s findings on the significant role of socioeconomic status in cancer risk.

5.2.4.5. Food Insecurity

The analysis highlights a significant and complex relationship between food insecurity and the likelihood of developing cancer, with the impact intensifying as the severity of food insecurity increases. The regression results are presented in the table 5.2.1.5.1. In the unadjusted model, individuals in the WITHOUT HUNGER category have 28.4% lower odds of cancer compared to those who are food secure, suggesting a potential protective effect of mild food insecurity. However, this association disappears in the adjusted model, indicating that other factors may confound this relationship. For individuals experiencing W/MOD. HUNGER, the unadjusted model shows a non-significant increase in odds, but after controlling for covariates such as age, income, education, and lifestyle factors, the risk becomes significant, with a 40.1% higher likelihood of cancer. The most striking finding is for individuals in the W/SEVERE HUNGER category, who have a 59.4% higher odds of cancer in the unadjusted model and an alarming 152.2% higher odds in the adjusted model. This dramatic increase underscores the severe health implications of prolonged and extreme food insecurity.

The adjusted model further reveals important contextual factors. Higher education levels, while typically protective for many health outcomes, are associated with increased odds of

cancer, likely reflecting higher rates of cancer screening and detection among more educated individuals. Age also plays a critical role, with older individuals—particularly those over 70—showing significantly higher odds of cancer, consistent with established age-related risk factors. Household income demonstrates a strong protective effect, with higher income groups experiencing substantially lower odds of cancer, reflecting better access to nutritious food, healthcare, and preventative measures. Additionally, marital status influences cancer risk, with single individuals showing lower odds, which may point to disparities in healthcare access or social support systems.

The results align with a study done by Gany et al. (2014). They assessed the prevalence and predictors of food insecurity among underserved oncology patients at cancer clinics in New York City. Using a demographic survey and the U.S. Household Food Security Survey Module, the study analyzed data from 404 participants through a multivariate General Linear Model Analysis of Covariance. Results showed that 18% of patients experienced very low food security, 38% low, 17% marginal, and 27% high. Predictors of food insecurity included younger age, Spanish as a primary language, poor healthcare access, and reduced financial resources for food due to cancer treatment. Food insecurity rates in this cohort were nearly five times the state average, underscoring the need for further research on its causes and impact in cancer and chronic disease patients.

Overall, the findings emphasize the critical role of food insecurity as a risk factor for cancer, particularly at moderate and severe levels. Severe hunger significantly elevates cancer risk, likely due to the compounded effects of chronic nutritional deficiencies, heightened stress, and limited access to healthcare. These results highlight the urgent need for targeted public health interventions to address food insecurity and its broader social determinants. Improving access to affordable, nutritious food and healthcare could play a pivotal role in reducing cancer disparities and improving health outcomes for vulnerable populations.

5.2.5. Summary

Across many Canadian provinces, high levels of overall fruit and vegetable consumption tend to exhibit protective effects against chronic diseases such as diabetes, high blood pressure, and heart disease. However, moderate intake often does not yield the same health benefits, suggesting a threshold effect in which protective benefits arise predominantly at high consumption levels.

Specific Produce Types

When examining individual fruits and vegetables, certain types show stronger associations with disease prevention. Non-starchy vegetables—such as leafy greens—and low-sugar items like fruit juice are frequently linked to reduced risks of high blood pressure and heart disease. Conversely, starchy vegetables, particularly potatoes and carrots, are associated with an increased risk of multiple chronic conditions, including diabetes, high blood pressure, and heart disease. These findings indicate that not all fruits and vegetables confer equal benefits, underscoring the importance of distinguishing between specific produce types in dietary guidance.

Income and Education Effects

The analysis highlights a consistent association between higher income and education levels and lower odds of chronic diseases across provinces. This pattern suggests that socioeconomic status influences dietary quality, access to health resources, and preventive care measures. For instance, in provinces such as Ontario, Quebec, and British Columbia, income levels emerge as significant predictors for the risk of diabetes and heart disease, underscoring the role of socioeconomic factors in chronic disease prevention.

Preparation and Dietary Patterns

The impact of specific types of vegetables, such as potatoes and carrots, varies by region, potentially due to differences in preparation methods (e.g., frying, baking) and dietary habits. For example, potatoes are commonly associated with increased odds of chronic diseases across various provinces, likely due to the prevalence of high-glycemic cooking methods. These findings highlight the importance of understanding regional dietary practices and their implications for health outcomes.

5.2.6. Implications

Tailored Recommendations by Produce Type

The nuanced relationships found across provinces support the need for tailored dietary guidelines that distinguish between types of fruits and vegetables. Higher consumption of non-starchy vegetables and lower-glycemic fruits, alongside limited intake of high-starch items such as potatoes, appears to offer protective benefits across regions. This tailored approach could lead to more effective dietary strategies for chronic disease prevention.

Consideration of Socioeconomic Factors

Given the impact of income and education levels on chronic disease risk, dietary recommendations should consider accessibility and affordability to promote healthier food choices among various socioeconomic groups. Emphasizing nutrient-dense and low-cost produce options may help improve public health outcomes on a broader scale.

Emphasizing High Consumption Levels

Protective effects against chronic diseases like diabetes, heart disease, and high blood pressure are most pronounced at high levels of fruit and vegetable consumption. Public health campaigns should prioritize encouraging individuals to achieve higher intake thresholds to maximize health benefits, rather than solely focusing on moderate consumption.

Improving Food Preparation Practices

Starchy vegetables like potatoes are often consumed in forms that exacerbate health risks (e.g., fried or baked at high temperatures). Public health strategies should include education on healthier cooking methods, such as steaming or boiling, to reduce the negative impacts of high-glycemic foods.

Regional Dietary Tailoring

Significant provincial variations in dietary patterns and chronic disease associations suggest the need for region-specific interventions. For example, promoting locally accessible nutrient-dense produce and addressing regional dietary habits can enhance the effectiveness of public health policies.

Incorporating Food Insecurity Interventions

The link between severe food insecurity and increased risks of chronic diseases highlights the importance of addressing nutritional deficiencies among vulnerable populations. Expanding food assistance programs, increasing subsidies for healthy foods, and ensuring access to healthcare services can play pivotal roles in reducing disease prevalence.

Promoting Lifelong Dietary Habits

The age-specific analysis indicates that dietary interventions should start early and evolve throughout life. Educational programs in schools and workplaces can establish healthy eating patterns, while older adults may benefit from policies that integrate dietary guidance into chronic disease management programs.

Integrating Policy and Public Health Efforts

Combining dietary recommendations with broader public health initiatives—such as

diabetes screening, heart health campaigns, and education on reducing processed foods—can amplify the impact of dietary changes. Collaborative efforts between policymakers, healthcare providers, and community organizations can create a comprehensive approach to reducing chronic disease risks.

Chapter 6 - Conclusions and Recommendations

This study aimed to investigate the impact of fruit and vegetable consumption and food insecurity on chronic disease prevalence among Canadians, with a particular focus on regional, demographic, and socioeconomic variations. Using data from the Canadian Community Health Survey (CCHS) spanning 2004 to 2020, the research employed logistic regression models to explore the relationship between dietary habits, food security status, and the presence of chronic diseases such as cardiovascular diseases, high blood pressure, diabetes, and cancer.

The findings of this study provide compelling evidence that dietary habits and food insecurity significantly influence chronic disease outcomes, with nuanced variations across disease types, demographic groups, and regions. Higher consumption of fruits and vegetables is associated with a decreased likelihood of developing diabetes, high blood pressure, heart disease, and cancer, emphasizing the protective role of a nutrient-rich diet. However, for cancer, the association is less consistent, with preparation methods and specific types of produce playing a critical role. Our findings align with those of McLeod and Veall (2006), who highlighted the protective effects of fruit and vegetable consumption against chronic diseases. Similar to their study, we observed that higher intake of fruits and vegetables was associated with reduced odds of these conditions, likely due to their anti-inflammatory and antioxidant properties. These results reinforce the importance of promoting fruit and vegetable consumption as a key strategy for chronic disease prevention and public health improvement.

Table 6.1. Summary table by selected Regional parameters

Parameters		**Result**
National		High fruit/veg consumption reduces risk
Provincial	Quebec	High intake reduces risk; starchy vegetables increase risk
	British Columbia	Strong protective effects against diseases
	Newfoundland	Starchy vegetables increase the risk
	Alberta	Aggregate fruit and vegetable consumption had limited or non-significant effects
	Manitoba	Notable benefits of salads and leafy greens
	Ontario	High fruit and vegetable consumption had strong protective effects against chronic diseases

Provinces like Quebec and British Columbia demonstrate stronger protective effects of fruit and vegetable consumption for diseases like diabetes, high blood pressure, and heart

disease. These advantages likely stem from regional dietary patterns, socioeconomic benefits, and better access to healthcare and quality produce. Conversely, provinces such as Newfoundland and Manitoba show weaker associations or increased risks, particularly for heart disease and cancer, highlighting the need for tailored interventions. For cancer, protective effects are observed in provinces with a focus on leafy greens and salads (e.g., Quebec). However, starchy vegetables like potatoes, particularly in British Columbia and Newfoundland, are linked to increased risk, underscoring the importance of preparation methods in dietary recommendations.

Provinces with higher average income and education levels (e.g., Ontario, British Columbia, Quebec) generally show stronger protective effects across all chronic diseases. These advantages likely facilitate better access to high-quality produce, health literacy, and preventive healthcare. In contrast, provinces with lower socioeconomic indicators (e.g., Newfoundland, New Brunswick, Manitoba) exhibit weaker benefits or higher risks, particularly for diabetes and high blood pressure, reflecting the broader impact of income inequality, food insecurity, and limited healthcare access.

Table 6.2. Summary table by Demographic, Socioeconomic, and Food Insecurity parameters

Parameters	**Results**
Age	High consumption reduces risks in older population; limited effects in younger population
Income	Protective effects more pronounced in high income groups
Food Insecurity	Severe food insecurity significantly increases the risk

Older adults, particularly those aged 55 and above, consistently benefit from high fruit and vegetable consumption, with notable reductions in the risk of diabetes, high blood pressure, and heart disease. However, younger populations show minimal effects, emphasizing the importance of establishing healthy dietary habits early in life. For cancer, the benefits of fruit and vegetable consumption vary significantly, with preparation methods and dietary balance playing a critical role across all age groups.

Food insecurity emerges as a critical determinant of chronic disease prevalence, particularly for diabetes and heart disease. Individuals experiencing moderate to severe food insecurity are more likely to consume low-cost, energy-dense, and nutrient-poor foods, exacerbating the risk of obesity, diabetes, and cardiovascular conditions. This impact is most

pronounced among low-income households and residents of rural or remote areas with limited access to fresh produce.

These findings emphasize the urgent need for targeted public health interventions addressing social determinants of health, including income inequality, education, and access to nutritious food. Policies should prioritize increasing fruit and vegetable intake while addressing barriers such as food insecurity, particularly in vulnerable populations and regions with weaker protective effects. Tailored strategies focusing on non-starchy vegetables and healthier preparation methods can optimize benefits for diseases like cancer and heart disease. In summary, this research underscores the critical role of dietary habits and food security in mitigating chronic disease risk and supports the development of policies promoting equitable access to healthy food and preventive healthcare.

6.1. Effective Strategies for Increasing Fruit and Vegetable Intake: Insights from Canada and Beyond

6.1.1. Global Examples of Policies to Increase Fruit and Vegetable Intake

Effective policies to increase fruit and vegetable intake encompass a range of economic, accessibility, educational, and regulatory interventions. Economic strategies, such as pricing incentives and subsidies, have demonstrated significant impacts. For instance, a 10% price reduction has been associated with a 14% increase in fruit and vegetable consumption in high-income countries and South Africa, with the combined use of subsidies and taxes on unhealthy foods showing the largest effect (Food and Agriculture Organization [FAO], 2021). Additionally, implementing substantial discounts, such as over 85% on vegetables, has proven effective in increasing intake among low-income populations (PMC, 2022).

Improving geographic and economic access also plays a crucial role. Initiatives like mobile markets and farm stands, alongside government support for weekly farmers' markets and incentives for local supermarkets to stock fresh produce, have effectively increased vegetable intake, particularly in underserved areas (FAO, 2021; WHO, 2024). Public investments in infrastructure, including road improvements and storage facilities, further enhance access by facilitating better distribution networks (FAO, 2021).

Educational and behavioral interventions offer another avenue for promoting fruit and vegetable consumption. School-based programs, such as direct provision of healthy foods, have

increased intake by 0.28 servings per day among children, with school meal standards enhancing fruit intake by an additional 0.76 servings per day (FAO, 2021). Broader community-based efforts targeting parents and children have also shown positive outcomes (National Library of Medicine [NLM], 2011). Similarly, workplace cafeteria interventions have increased fruit and vegetable intake through strategies like adding healthier options, increasing portion sizes, and removing unhealthy items (FAO, 2021).

Policy and regulatory approaches include food-based dietary guidelines and public procurement policies. Developing and updating these guidelines as a foundation for other interventions can encourage healthier eating habits (FAO, 2021). Additionally, enabling small farmers to supply school meal programs, as implemented in Brazil, has proven effective in increasing fruit and vegetable consumption (FAO, 2021). Comprehensive approaches that combine multiple strategies—such as subsidies, improved access, and educational initiatives—are particularly impactful in fostering sustainable dietary improvements (FAO, 2021; WHO, 2024).

The effectiveness of these policies depends on local contexts and population-specific needs, emphasizing the importance of tailored interventions. Combining multiple strategies to address economic, geographic, and educational barriers can yield the most significant results in increasing fruit and vegetable intake (FAO, 2021; WHO, 2024).

6.1.2. Existing Policies to Promote Fruit and Vegetable Intake in Canada

Canada's Healthy Eating Strategy, launched in 2016, outlines a comprehensive approach to improving dietary habits and the food environment across the country. A cornerstone of this strategy is Canada's Food Guide, released in January 2019, which encourages Canadians to eat plenty of vegetables, fruits, whole grains, and protein foods while prioritizing plant-based proteins, making water the preferred beverage, and limiting highly processed foods (Ottawa Public Health, 2024; CHFA, 2024). Complementing this guidance are food labeling regulations, which include updated Nutrition Facts tables for easier product comparisons and the introduction of mandatory front-of-package nutrition symbols for foods high in sodium, sugars, and saturated fat, set to be fully implemented by 2026 (Government of Canada, 2024).

Another significant policy is the ban on trans fats, effective since September 2018, which eliminated partially hydrogenated oils, the primary source of industrially produced trans fats, from the food supply (Government of Canada, 2024). Sodium reduction initiatives are also part

of the strategy, with voluntary targets for the food industry to lower sodium levels in processed foods by 2025 (Government of Canada, 2024). Efforts to protect children from unhealthy dietary influences include proposed marketing restrictions on advertisements for certain foods directed at children, currently under development (Government of Canada, 2024).

The strategy also targets access to nutritious food in northern communities through programs like Nutrition North, which addresses barriers to healthy eating in remote areas (Biomed Central, 2022). Broader food environment improvements aim to simplify healthier choices for Canadians, emphasizing cooking at home, practicing mindful eating habits, and promoting shared meals (Food Secure Canada, 2024; Ottawa Public Health, 2024). Canadians are also encouraged to make informed dietary decisions by reading food labels and being aware of how food marketing may influence their choices (Ottawa Public Health, 2024; CHFA, 2024).

These initiatives reflect Canada's multifaceted approach to healthy eating, integrating public awareness, regulatory actions, and community support to foster healthier lifestyles. The strategy addresses the nutritional needs of diverse populations, ensuring that healthy food choices are accessible and informed by transparent labeling and education.

6.2. Future Directions for Promoting Healthy Eating

To effectively address dietary challenges and promote fruit and vegetable consumption, future initiatives must focus on enhancing access, expanding education, and fostering community involvement. These efforts should involve coordinated action at institutional and community levels, with specific responsibilities for governments, public institutions, and local organizations.

6.2.1. Institutional Level

Enhance Access to Healthy Foods

Governments and healthcare institutions should implement policies aimed at increasing access to affordable and nutritious foods, especially in underserved regions. Strategies may include subsidizing fresh produce, supporting local food supply chains, and providing incentives for grocery stores to operate in food deserts. Additionally, tax reductions on healthy food items and increased taxes on unhealthy foods could help shift consumer choices towards healthier options.

Promote Nutrition Education Programs

Nutrition education should be integrated into public health initiatives to raise awareness

about the benefits of fruit and vegetable consumption. Programs targeting schools, workplaces, and healthcare settings can empower individuals to make healthier dietary choices. Educational campaigns should focus on practical advice for incorporating more fruits and vegetables into daily meals and understanding the long-term health impacts of poor dietary habits.

Implement Healthy Eating Policies

Public institutions such as schools, hospitals, and government offices should adopt policies that promote healthy eating environments. This could include offering healthier meal options in cafeterias, restricting the availability of sugary and processed foods, and encouraging farm-to-table initiatives. Institutions should also support guidelines that recommend daily servings of fruits and vegetables as part of balanced diets.

6.2.2. Community Involvement

Support Community Gardens and Local Food Programs

Community gardens and local food programs are effective ways to improve access to fresh produce, particularly in urban and low-income areas. These initiatives not only enhance food security but also foster a sense of community and encourage healthy eating habits. Municipal governments and non-profit organizations should provide resources and support to establish and maintain these gardens, ensuring that they are accessible to all community members.

Encourage Community-Based Food Security Programs

Expanding community-based food security programs, such as food banks, community kitchens, and farmers' markets, can help address the immediate needs of food-insecure individuals. These programs should be designed to provide not only food assistance but also nutrition education and support for cooking and meal planning. Involving local communities in the design and delivery of these services can increase their effectiveness and sustainability.

Foster Partnerships with Local Organizations

Collaboration between local governments, health organizations, non-profits, and community groups is essential for developing and implementing effective interventions. Partnerships can help pool resources, share expertise, and create tailored solutions that address the specific needs of different communities. For example, joint initiatives could focus on improving food access in remote areas, providing culturally appropriate nutrition education, and supporting local food production.

Promoting fruit and vegetable consumption requires a multi-faceted approach that combines institutional support with community engagement. By enhancing access, prioritizing education, and fostering collaboration, governments, organizations, and communities can work together to create a healthier food environment. These efforts will not only reduce disparities in food access but also improve the overall health and well-being of populations, laying the groundwork for sustainable dietary improvements.

6.3. Funding to Support Future Healthy Eating Policies

Implementing future healthy eating policies and programs requires a diverse array of funding sources, combining government budgets, private sector contributions, grants, and community partnerships. Government funding plays a critical role, with federal budgets supporting large-scale initiatives such as subsidies for fresh produce, nutrition education campaigns, and infrastructure improvements in underserved regions. Programs like Nutrition North Canada could benefit from increased federal investment to enhance access to healthy foods in remote areas. Similarly, provincial and municipal governments are essential in funding community-specific initiatives, including urban gardening projects, farmers' markets, and school-based nutrition programs. Revenues generated through taxes on unhealthy foods, such as sugary beverages, can also provide a significant funding stream, as demonstrated by successful "sugar tax" models in countries like Mexico and the UK (Gomez, 2023). This revenue can be redirected to subsidize healthy eating programs and further public health goals.

Private sector contributions and public-private partnerships (PPPs) are equally important for sustaining these initiatives. Companies, particularly in the food and beverage industry, can support healthier communities through corporate social responsibility (CSR) programs, such as sponsoring food access programs or investing in partnerships with food banks (Barata et al., 2020). PPPs allow governments and private entities to pool resources for large-scale projects, such as subsidized grocery programs or mobile markets, which combine public investment with private capital. Additionally, grants and philanthropic funding from non-profits, foundations, and global health organizations provide critical support for grassroots initiatives and research. Community contributions, including volunteer efforts, crowdfunding, and local fundraising, also enhance program sustainability and ensure community buy-in. Finally, cost savings achieved through reduced healthcare expenditures on diet-related chronic diseases can be reinvested into

prevention programs, creating a self-sustaining cycle. By leveraging these diverse funding streams, future healthy eating policies can be implemented effectively and sustainably, ensuring long-term benefits for all Canadians.

6.4. The Role of Public Health Canada in Facilitating Healthy Eating Policies

Public Health Canada must adopt a proactive role in facilitating and implementing healthy eating policies to ensure their success. As the nation's primary public health authority, its leadership is essential in developing comprehensive strategies, addressing systemic barriers, and coordinating stakeholders to promote healthier dietary habits across the country. This involves spearheading policy development and revision based on the latest research, advocating for increased funding at both federal and provincial levels, and enforcing regulations such as food labeling standards and restrictions on marketing unhealthy foods. Public Health Canada must also ensure compliance with initiatives like sodium reduction targets while creating targeted interventions for vulnerable populations, including low-income households and residents of rural and remote areas, to address disparities in access to healthy foods.

A key aspect of Public Health Canada's proactive approach should include implementing large-scale public awareness campaigns to educate Canadians on the benefits of healthy eating and the role of fruits and vegetables in preventing chronic diseases. This can be complemented by culturally tailored educational materials that cater to the country's diverse populations, along with grassroots-level engagement through community partnerships. Addressing the social determinants of health is also critical, including tackling food insecurity by subsidizing fresh produce and improving food access in underserved regions. Furthermore, Public Health Canada must prioritize research and innovation, funding studies to evaluate policy effectiveness, leveraging health data for evidence-based decisions, and piloting new initiatives like mobile markets and community gardens. By fostering partnerships with private sector entities and international organizations, Public Health Canada can align resources and adopt global best practices to strengthen its efforts. This leadership-oriented approach not only improves dietary habits and reduces chronic disease prevalence but also bolsters the resilience of Canada's healthcare system.

6.5. Limitations of This Study

The study focuses on the Canadian context, utilizing national survey data to explore the relationships between dietary habits, food insecurity, and chronic diseases. While the study aims to provide comprehensive insights, there are several limitations to consider.

Data Limitations

The study relies on self-reported data for dietary intake and food insecurity status, which may introduce bias due to inaccurate reporting or recall errors. Additionally, the cross-sectional nature of the data limits the ability to establish causal relationships between dietary factors and chronic disease outcomes.

A significant limitation of this study is the exclusion of several key variables that could influence the observed relationships between fruit and vegetable consumption, food insecurity, and chronic disease outcomes. These omitted variables include genetic predisposition to chronic diseases, stress levels, healthcare access, sleep quality, and physical activity. For instance, regular exercise and adequate sleep are known to reduce stress, improve metabolic health, and decrease inflammation—factors that are independently associated with lower chronic disease risks. Individuals who exercise and maintain good sleep hygiene may also be more likely to consume fruits and vegetables, creating potential confounding effects. The absence of these variables may introduce omitted variable bias, potentially leading to an overestimation or underestimation of the effects of fruit and vegetable consumption. For example, the observed health benefits attributed to higher fruit and vegetable intake may partially reflect the influence of healthier overall lifestyles among individuals who exercise, sleep well, and experience lower stress levels.

Furthermore, the study does not differentiate between types of fruit juice consumed or their sugar content. This limitation is critical because fruit juices can range from nutrient-dense options, like fresh-squeezed orange juice, to sugar-laden, highly processed beverages. The inability to distinguish between these variations prevents a more granular analysis of how specific types of fruit juice contribute to health outcomes. As a result, the strong associations observed in this study may reflect the average effects across all types of fruit juices, masking potential differential impacts.

Future studies should address these limitations by incorporating data on omitted variables, such as lifestyle factors and healthcare access, alongside more detailed information on fruit juice types, sugar levels, and processing methods. This would provide a more

comprehensive and nuanced understanding of the complex interactions among dietary habits, lifestyle behaviors, and health outcomes.

Geographical Constraints

The research primarily focuses on data from Canada, which may limit the applicability of the findings to other countries with different dietary patterns, food security challenges, and healthcare systems. Regional variations within Canada also mean that some findings may not be generalizable across all provinces and territories.

Lack of Longitudinal Data

The absence of longitudinal data restricts the ability to observe long-term impacts of changes in dietary habits and food security status on chronic disease development. Future research with longitudinal designs would provide a more comprehensive understanding of how these factors evolve over time.

6.6. Further Research

To build upon the findings of this study, future research should consider the following areas,

Longitudinal Studies

Future studies should employ longitudinal designs to explore how changes in fruit and vegetable consumption and food security status affect chronic disease outcomes over time. This approach would allow for a better understanding of causality and the long-term effects of dietary interventions.

Interventional Studies

Research should focus on the implementation and evaluation of community-based interventions, such as nutrition education programs, food access initiatives, and policy changes. Evaluating the effectiveness of these interventions can provide evidence for best practices in reducing chronic disease risk.

Exploring Other Dietary Factors

While this study focused on fruit and vegetable consumption, further research should investigate the role of other dietary components, such as processed foods, sugar intake, and specific micronutrients, in relation to chronic disease prevalence. Understanding the broader dietary context will help refine public health recommendations.

Focus on Vulnerable Populations

Additional research is needed to explore the unique challenges faced by vulnerable groups, including Indigenous populations, seniors, and individuals living in remote regions. Tailored interventions that address the specific needs of these populations could significantly improve health outcomes.

Policy Impact Analysis

Evaluating the effectiveness of existing food security and dietary policies at both the institutional and community levels would provide valuable insights into areas of success and opportunities for improvement. Policy impact analysis could guide future policy development and resource allocation.

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Appendix

Table 5.1.1.3. Summary table for the chronic disease status variables

Chronic Disease Status	Frequency	Percent	Cumulative Percent
CDS: At least one chronic disease			
(No)	481,430	72.17%	72.17%
(Yes)	185,603	27.83%	100.00%
CDS_4: All four chronic diseases			
(No)	666,512	99.92%	99.92%
(Yes)	521	0.08%	100.00%
CDS_3: Three chronic diseases			
(No)	657,219	98.53%	98.53%
(Yes)	9,814	1.47%	100.00%
CDS_2: Two chronic diseases			
(No)	618,658	92.75%	92.75%
(Yes)	48,375	7.25%	100.00%
CDS_1: Only one chronic disease			
(No)	532,211	79.79%	79.79%
(Yes)	134,822	20.21%	100.00%

Table 5.1.1.4. Frequency of Chronic Disease Prevalence by Fruit and Vegetable Consumption Levels

Fruit & Vegetable Consumption	High Blood Pressure - No	High Blood Pressure - Yes	Diabetes - No	Diabetes - Yes	Heart Disease - No	Heart Disease - Yes	Cancer - No	Cancer - Yes
Low Consumption	170,596	44,737	198,623	16,710	201,498	13,835	202,877	4,216
Moderate Consumption	227,428	67,426	271,112	23,742	274,513	20,341	277,129	7,056
High Consumption	126,237	30,609	146,446	10,400	147,865	8,981	149,685	3,725
Total	524,261	142,772	616,181	50,852	623,876	43,157	629,691	14,997

Table 5.1.2.1. Fruit & Vegetable Consumption by Province

Province	Low Consumption	Moderate Consumption	High Consumption
Newfoundland	7137	8446	3115
PEI	5823	6666	2669
Nova Scotia	9141	13587	5560
New Brunswick	6727	10679	5376
Quebec	23938	50440	37132
Ontario	81505	96818	49536
Manitoba	10107	16343	7193
Saskatchewan	10186	17859	8351
Alberta	27372	31237	15594
British Columbia	27668	35906	18696
Yukon/NWT/Nunavut	5729	6873	3624
Total	215333	294854	156846

Table 5.1.5.3. Disease Prevalence by Household Food Insecurity

Chronic Disease	Food Secure (%)	Without Hunger (%)	With Moderate Hunger (%)	With Severe Hunger (%)	Total (%)
Diabetes - NO	92.85	4.77	2.3	0.09	100
Diabetes - YES	91.3	5.41	3.19	0.1	100
High Blood Pressure - NO	92.45	5.06	2.4	0.09	100
High Blood Pressure - YES	93.77	3.93	2.24	0.07	100
Heart Disease - NO	92.71	4.86	2.34	0.09	100
Heart Disease - YES	93.02	4.21	2.63	0.14	100
Cancer - NO	92.75	4.88	2.28	0.09	100
Cancer - YES	93.66	3.71	2.46	0.17	100

Table 5.1.4.1. Sex Distribution

Sex	Frequency	Percent
Male	303208	45.46
Female	363825	54.54
Total	667033	100

Table 5.1.4.3. Marital status Distribution

Marital Status	Frequency	Percent
Married	284455	42.79
Common-Law	66010	9.93
Widow/Separated/Divorced	123289	18.55
Single	190976	28.73
Total	664730	100

Table 5.1.5.1. Education Distribution

Education Level	Frequency	Percent
< Than Secondary	143393	23.88
Secondary Grad.	104097	17.34
Other Post-Sec.	101702	16.94
Post-Sec. Grad.	251240	41.84
Total	600432	100

Table 5.1.6.1. Alcohol Consumption Distribution

Drank Alcohol in Past 12 Months	Frequency	Percent
Yes	503827	78.02
No	141980	21.98
Total	645807	100

Table 5.1.6.2. BMI Distribution

BMI Classification	Frequency	Percent
Underweight	29195	4.38
Normal weight	275834	41.35
Overweight	200752	30.1
Obese - Class I, II, III	161252	24.17
Total	667033	100

Table 5.1.1.4. Frequency of Chronic Disease Prevalence by Fruit and Vegetable Consumption Levels

Fruit & Vegetable Consumption	High Blood Pressure - No	High Blood Pressure - Yes	Diabetes - No	Diabetes - Yes	Heart Disease - No	Heart Disease - Yes	Cancer - No	Cancer - Yes
Low Consumption	170,596	44,737	198,623	16,710	201,498	13,835	202,877	4,216
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Yukon/NWT/Nunavut	5729	6873	3624
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High Blood Pressure - YES	93.77	3.93	2.24	0.07	100
Heart Disease - NO	92.71	4.86	2.34	0.09	100
Heart Disease - YES	93.02	4.21	2.63	0.14	100
Cancer - NO	92.75	4.88	2.28	0.09	100
Cancer - YES	93.66	3.71	2.46	0.17	100

Table 5.1.4.1. Sex Distribution

Sex	Frequency	Percent
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Female	363825	54.54
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Total	600432	100

Table 5.1.6.1. Alcohol Consumption Distribution

Drank Alcohol in Past 12 Months	Frequency	Percent
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No	141980	21.98
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Table 5.1.6.2. BMI Distribution

BMI Classification	Frequency	Percent
Underweight	29195	4.38
Normal weight	275834	41.35
Overweight	200752	30.1
Obese - Class I, II, III	161252	24.17
Total	667033	100

Table 5.1.2.2. Disease Prevalence by Province

Province	HBP - No (Freq)	HBP - Yes (Freq)	HBP - No (%)	HBP - Yes (%)	Diabetes - No (Freq)	Diabetes - Yes (Freq)	Diabetes - No (%)	Diabetes - Yes (%)	Heart Disease - No (Freq)	Heart Disease - Yes (Freq)	Heart Disease - No (%)	Heart Disease - Yes (%)	Cancer - No (Freq)	Cancer - Yes (Freq)	Cancer - No (%)	Cancer - Yes (%)
Newfoundland	13896	4802	2.65	3.36	16739	1959	2.72	3.85	17356	1342	2.78	3.11	18293	405	2.91	2.7
PEI	11288	3870	2.15	2.71	13701	1457	2.22	2.87	13754	1404	2.2	3.25	11499	272	1.83	1.81
Nova Scotia	20714	7574	3.95	5.3	25415	2873	4.12	5.65	25825	2463	4.14	5.71	23255	679	3.69	4.53
New Brunswick	16962	5820	3.24	4.08	20684	2098	3.36	4.13	20998	1784	3.37	4.13	22147	635	3.52	4.23
Quebec	88759	22751	16.93	15.94	103401	8109	16.78	15.95	104294	7216	16.72	16.72	109058	2452	17.32	16.35
Ontario	177949	49910	33.94	34.96	210006	17853	34.08	35.11	212482	15377	34.06	35.63	222219	5640	35.29	37.61
Manitoba	26477	7166	5.05	5.02	31266	2377	5.07	4.67	31720	1923	5.08	4.46	32940	703	5.23	4.69
Saskatchewan	27623	8773	5.27	6.14	33361	3035	5.41	5.97	33806	2590	5.42	6	30854	707	4.9	4.71
Alberta	59960	14243	11.44	9.98	69413	4790	11.27	9.42	70400	3803	11.28	8.81	63037	1397	10.01	9.32
British Columbia	66613	15657	12.71	10.97	76808	5462	12.47	10.74	77552	4718	12.43	10.93	80380	1890	12.76	12.6
Yukon/NWT/Nunavut	14020	2206	2.67	1.55	15387	839	2.5	1.65	15689	537	2.51	1.24	16009	217	2.54	1.45
Total	524261	142772	100	100	616181	50852	100	100	623876	43157	100	100	629691	14997	100	100

Table 5.1.4.3. Disease Prevalence by Household Income

Household Income	HBP - No (Freq)	HBP - Yes (Freq)	HBP - No (%)	HBP - Yes (%)	Diabetes - No (Freq)	Diabetes - Yes (Freq)	Diabetes - No (%)	Diabetes - Yes (%)	Heart Disease - No (Freq)	Heart Disease - Yes (Freq)	Heart Disease - No (%)	Heart Disease - Yes (%)	Cancer - No (Freq)	Cancer - Yes (Freq)	Cancer - No (%)	Cancer - Yes (%)
No Income	44999	20952	8.58	14.68	56999	8952	9.25	17.6	58169	7782	9.32	18.03	62720	2282	9.96	15.22
< $15,000	90053	39436	17.18	27.62	114889	14600	18.65	28.71	116047	13442	18.6	31.15	121457	4292	19.29	28.62
$15,000-$29,999	94452	29115	18.02	20.39	113642	9925	18.44	19.52	115050	8517	18.44	19.73	116708	3131	18.53	20.88
$30,000-$49,999	89264	20292	17.03	14.21	102673	6883	16.66	13.54	103991	5565	16.67	12.89	104239	2090	16.55	13.94
$50,000-$79,999	196498	31437	37.48	22.02	217988	9947	35.38	19.56	220509	7426	35.35	17.21	214209	3025	34.02	20.17
$80,000 or More	8995	1540	1.72	1.08	9990	545	1.62	1.07	10110	425	1.62	0.98	10358	177	1.64	1.18
Total	524261	142772	100	100	616181	50852	100	100	623876	43157	100	100	629691	14997	100	100

Table 5.1.3.3. Disease Prevalence by Age Group

Age Group	HBP - No (Freq)	HBP - Yes (Freq)	HBP - No (%)	HBP - Yes (%)	Diabetes - No (Freq)	Diabetes - Yes (Freq)	Diabetes - No (%)	Diabetes - Yes (%)	Heart Disease - No (Freq)	Heart Disease - Yes (Freq)	Heart Disease - No (%)	Heart Disease - Yes (%)	Cancer - No (Freq)	Cancer - Yes (Freq)	Cancer - No (%)	Cancer - Yes (%)
12 to 24 years	84675	18557	16.15	13	97403	5829	15.81	11.46	94369	8863	15.13	20.54	99791	2418	15.85	16.12
25 to 39 years	124991	3414	23.84	2.39	127107	1298	20.63	2.55	127640	765	20.46	1.77	125375	284	19.91	1.89
40 to 54 years	122462	13092	23.36	9.17	130730	4824	21.22	9.49	133471	2083	21.39	4.83	131548	1037	20.89	6.91
55 to 69 years	121949	48125	23.26	33.71	153116	16958	24.85	33.35	158813	11261	25.46	26.09	162089	4719	25.74	31.47
70 years or more	70184	59584	13.39	41.73	107825	21943	17.5	43.15	109583	20185	17.56	46.77	110888	6539	17.61	43.6
Total	524261	142772	100	100	616181	50852	100	100	623876	43157	100	100	629691	14997	100	100

Table 5.1.3.1. Percentage Distribution of Chronic Disease Prevalence by Fruit and Vegetable Consumption Levels

Fruit & Vegetable Consumption	High Blood Pressure - No (%)	High Blood Pressure - Yes (%)	Diabetes - No (%)	Diabetes - Yes (%)	Heart Disease - No (%)	Heart Disease - Yes (%)	Cancer - No (%)	Cancer - Yes (%)
Low Consumption	32.54	31.33	32.23	32.86	32.30	32.06	32.22	28.11
Moderate Consumption	43.38	47.23	44.00	46.69	44.00	47.13	44.01	47.05
High Consumption	24.08	21.44	23.77	20.45	23.70	20.81	23.77	24.84
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 5.2.3.1.1 Logistic Regression Results for Probability of Heart Disease

	Model 1 (Univariate)	Model 2 (Multivariate)
Constant	-2.6786*** (0.0428)	-0.9581*** (0.0456)
Fruit and Vegetable Consumption (fru_veg_cat)		
Moderate Consumption	0.0762*** (0.0264)	-0.0029 (0.0133)
High Consumption	-0.1226*** (0.0378)	-0.0610*** (0.0208)
Alcohol Consumption		
No		0.2658*** (0.0138)
Education		
Secondary Graduate		-0.0066 (0.0183)
Other Post-Secondary		-0.0036 (0.0248)
Post-Secondary Graduate		0.0690**(0.0269)
Household Income		
Less than $15,000		-0.2935*** (0.0228)
$15,000-$29,999		-0.5913***(0.0333)
$30,000-$49,999		-0.7241*** (0.0342)
$50,000-$79,999		-1.0135*** (0.0581)
$80,000 or more		-0.9749*** (0.0450)
Year Indicators		Yes
Age		
25 to 39 years		-2.7937*** (0.0881)
40 to 54 years		-2.1557*** (0.0841)
55 to 69 years		-0.8068*** (0.0697)
70 years or more		-0.0897 (0.0634)
Sex (Female)		-0.5841*** (0.0142)
Marital Status		
Common-Law		-0.1451*** (0.0470)
Widow/Separated/Divorced		0.0304 (0.0185)
Single		-1.3715*** (0.0906)
Province Indicators		Yes
Pseudo R-squared	0.0007	0.1480
Observations	667,033	579,304

Standard errors are reported in parentheses.
Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01

Table 5.2.4.1.1. Logistic Regression Results for Probability of Cancer

	Model 1 (Univariate)	Model 2 (Multivariate)
Constant	-3.8737*** (0.0686)	-3.2588*** (0.0801)
Fruit and Vegetable Consumption (fru_veg_cat)		
Moderate Consumption	0.2031*** (0.0465)	0.0234 (0.0177)
High Consumption	0.1803*** (0.0601)	0.0622*** (0.0167)
Alcohol Consumption		
No		0.0902** (0.0309)
Education		
Secondary Graduate		0.1320*** (0.0363)
Other Post-Secondary		0.1629*** (0.0298)
Post-Secondary Graduate		0.2939*** (0.0407)
Household Income		
Less than $15,000		-0.1492*** (0.0270)
$15,000-$29,999		-0.3101*** (0.0261)
$30,000-$49,999		-0.4471*** (0.0359)
$50,000-$79,999		-0.6252*** (0.0380)
$80,000 or more		-0.6651*** (0.1204)
Year Indicators		Yes
Age		
25 to 39 years		-2.5802*** (0.0892)
40 to 54 years		-1.5563*** (0.1012)
55 to 69 years		-0.3541*** (0.0804)
70 years or more		0.2239*** (0.0710)
Sex (Female)		-0.0950 (0.0707)
Marital Status		
Common-Law		-0.1282** (0.0572)
Widow/Separated/Divorced		-0.0245 (0.0188)
Single		-1.0887*** (0.0729)
Province Indicators		Yes
Pseudo R-squared	0.0008	0.0891
Observations	644,688	559,913

Standard errors are reported in parentheses.
Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01

Table 5.2.1.3.1. Logistic Regression Results for Probability of Diabetes by Age Distribution

	12 to 24 years	12 to 24 years	25 to 39 years	25 to 39 years	40 to 54 years	40 to 54 years	55 to 69 years	55 to 69 years	70 years or more	70 years or more
Constant	-2.928***	-1.235***	-4.625***	-5.075***	-3.226***	-3.496***	-2.109***	-2.037***	-1.480***	-1.350***
	(-36.06)	(-17.30)	(-72.39)	(-34.45)	(-30.82)	(-54.15)	(-38.12)	(-109.31)	(-22.40)	(-40.41)
Fruit and Vegetable Consumption (fru_veg_cat)										
Moderate Consumption	0.253***	-0.0672	0.0217	0.0732	-0.100	-0.0754	-0.0937	-0.0151	-0.109	-0.0677***
	(5.06)	(-1.56)	(0.45)	(1.22)	(-1.00)	(-1.62)	(-1.74)	(-0.62)	(-1.84)	(-3.75)
High Consumption	-0.0354	-0.105	0.124	0.130	-0.147	-0.109	-0.237***	-0.105*	-0.271***	-0.168***
	(-0.55)	(-1.84)	(1.82)	(1.84)	(-1.39)	(-1.94)	(-3.82)	(-2.55)	(-4.30)	(-5.92)
Education Indicators		Yes		Yes		Yes		Yes		Yes
Household Income Indicators		Yes		Yes		Yes		Yes		Yes
Year Indicators		Yes		Yes		Yes		Yes		Yes
Sex Indicators		Yes		Yes		Yes		Yes		Yes
Marital Status Indicators		Yes		Yes		Yes		Yes		Yes
Observations		103232	81174	128405	110024	135554	117745	170074	153129	129768

Standard errors are reported in parentheses.

Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01

Table 5.2.1.4.1. Logistic Regression Results for Probability of Diabetes by Income Distribution

	< $15,000		$15,000-$29,999		$30,000-$49,999		$50,000-$79,999		>$80,000	
Constant	-1.917***	-2.280***	-2.082***	-1.903***	-2.439***	-2.372***	-2.756***	-3.054***	-3.030***	-4.170***
	(-49.47)	(-88.49)	(-36.73)	(-37.49)	(-26.20)	(-19.02)	(-21.02)	(-14.78)	(-19.54)	(-21.79)
Fruit and Vegetable Consumption (fru_veg_cat)										
Moderate Consumption	0.142***	0.0857***	0.0784**	-0.00816	0.0591	-0.0957**	0.137	-0.0374	0.0156	-0.0969**
	-4.38	-3.38	-2.97	(-0.39)	-0.86	(-3.10)	-1.26	(-1.43)	-0.12	(-2.81)
High Consumption	0.0277	0.00252	-0.0775*	-0.0847***	-0.12	-0.188***	-0.034	-0.0971*	-0.273	-0.208***
	-0.82	-0.09	(-2.56)	(-3.60)	(-1.67)	(-4.57)	(-0.29)	(-2.28)	(-1.88)	(-4.11)
Education Indicators		Yes		Yes		Yes		Yes		Yes
Year Indicators		Yes		Yes		Yes		Yes		Yes
Sex Indicators		Yes		Yes		Yes		Yes		Yes
Marital Status Indicators		Yes		Yes		Yes		Yes		Yes
Age Indicators		Yes		Yes		Yes		Yes		Yes
Observations		65951	58763	129489	113906	123567	106019	109556	89707	227935

Standard errors are reported in parentheses.

Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01

Table 5.2.1.5.1. Logistic Regression Results for Probability of Diseases by Food Insecurity

	Diabetes		High Blood Pressure		Heart Diseases		Cancer	
Constant	-2.531***	-2.037***	-1.296***	-0.625***	-2.67***	-0.975***	-3.718***	-3.166***
	(0.05)	(0.07)	(0.05)	(0.08)	(0.04)	(0.06)	(0.07)	(0.08)
Food Insecurity								
Without Hunger	0.144***	0.266***	0.024***	0.003	-0.146***	0.135***	-0.284***	0.044
	(0.04)	(0.37)	(0.02)	(0.02)	(0.03)	(0.04)	(0.04)	(0.05)
With Moderate Hunger	0.345***	0.349***	-0.083*	0.131***	0.111	0.405***	0.069	0.401***
	(0.06)	(0.34)	(0.05)	(0.04)	(0.07)	(0.06)	(0.06)	(0.06)
With Severe Hunger	0.171	0.483***	-0.313***	0.009	0.468***	0.788***	0.594***	1.522***
	(0.08)	(0.04)	(0.08)	(0.04)	(0.07)	(0.04)	(0.07)	(0.06)
Education Indicators		Yes		Yes		Yes		Yes
Household Income Indicators		Yes		Yes		Yes		Yes
Year Indicators		Yes		Yes		Yes		Yes
Sex Indicators		Yes		Yes		Yes		Yes
Marital Status Indicators		Yes		Yes		Yes		Yes
Alcohol Consumption		Yes		Yes		Yes		Yes
Observations	589134	510,777	589134	510777	589134	510777	566789	491386

Standard errors are reported in parentheses.

Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01