

# **An unequal burden: Trends in prevalence and distribution of multimorbidity in Canada**

**Major Research Paper**

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## ABSTRACT

Multimorbidity poses a major challenge to health care systems around the world. In this study, I estimated the trends in prevalence of multimorbidity in the Canadian adult population. Furthermore, I substantiated the findings of Roberts et al. (2015) by examining the socio-economic and health and behavioural risk factors associated with multimorbidity.

I pooled the Canadian Community Health Survey cycles from 2007-2013 to obtain a sample size of 451, 734 Canadian adults. Multimorbidity was defined as two or more and three or more chronic diseases from a list of eight. I conducted logistic regression analysis to determine the overall and stratified by age groups time trends in prevalence of multimorbidity as well as determinants of multimorbidity.

Prevalence of two or more chronic diseases increased from 11.8% to 12.6% and three or more chronic diseases increased from 3.6% to 3.9% from 2007 to 2013 and this increase in prevalence of multimorbidity was largely due an ageing population. In the overall population, female sex, older age, low household income, being Canadian-born in comparison to being an immigrant, high blood pressure, high stress, obesity, smoking and physical inactivity were associated with multimorbidity.

With a rise in proportion of Canadians aged 65 years and older, the prevalence of multimorbidity is also expected to rise. This rising burden of multimorbidity will require health authorities to scale-up the successful integrated care pilots to improve the management of patients with multimorbidity. Since Canadians living in the lowest socio-economic group are more likely to develop multimorbidity, preventative measures such as social assistance programs will need continuous improvements to address the root causes of poor health outcomes.

## INTRODUCTION

According to the World Health Organization (WHO), chronic diseases have reached epidemic proportions and constitute the leading cause of death and disability in the world (WHO, 2014). Similarly, multimorbidity, defined as the co-occurrence of two or more chronic diseases within the same individual, is becoming increasingly common due to an ageing population, lowered thresholds for diagnosis, inclusion of new diagnoses, increased life expectancy achieved through advancements in medical care and possibly also as a result of a true increase in the prevalence of some chronic diseases (van den Akker et al., 1996; Pefoyo et al., 2015; van Oostrom et al., 2016; Dhalwani et al., 2016; Agborsangaya et al., 2012; Starfield, 2011).

Previous studies have shown that individuals with multimorbidity are at an increased for more frequent and longer hospitalizations and poor health outcomes partly due to psychological distress and interactions between drugs and adverse effects of drugs used for one disease on other diseases (Glynn et al., 2011; Fortin et al., 2007). Moreover, as in other industrialized nations, Canadian guidelines describing care of patients are typically oriented towards single diseases (Dawes, 2010). This poses a great challenge for primary health care professionals who try to implement the evidence from these guidelines while caring for patients with multiple diseases, thereby increasing the risk of the patient receiving substandard care.

To estimate the magnitude of the problem, a few studies have assessed the prevalence and the risk factors associated with multimorbidity in Canada. Fortin et al. (2010) estimated an overall multimorbidity prevalence rate of 11.6% in the population aged 25 years and over in Quebec. In Alberta, Agborsangaya et al. (2012) estimated an overall multimorbidity prevalence rate of 19% in the population aged 25 years and over. Pefoyo et al. (2015) reported that prevalence of multimorbidity in Ontario increased from 17.4% in 2003 to 24.3% in 2009 in the population aged

0 to 105 years. Roberts et al. (2015) were the first to report prevalence of multimorbidity at the national population level. They used the 2011/12 Canadian Community Health Survey (CCHS) to report that 12.9% of Canadians aged 20 years and over had two or more chronic diseases and 3.9% had three or more chronic diseases. The authors also reported that being female, older, living in the lowest household income quintile, Aboriginal status, physical inactivity, being a smoker, high stress levels and obesity were significantly associated with multimorbidity. Despite the expectation that prevalence will increase due to an ageing population and rising prevalence of chronic diseases (Ward et al., 2013; WHO, 2014), there is a lack of research with population-based analyses depicting time trends of multimorbidity in Canada.

In this study, to address notable gaps in the literature, I pooled the CCHS survey cycles from 2007-2013 to estimate the trends in prevalence of multimorbidity overtime in the Canadian population aged 20 years and above. Furthermore, to contribute towards existing research in the area of multimorbidity, I reproduced the findings of Roberts et al. (2015) but using a much larger sample by pooling together the CCHS survey cycles leads to a more robust analysis of the overall and stratified by age group association between socio-economic determinants and health and behavioural risk factors and multimorbidity in the Canadian population.

Overall, I demonstrate that the increase in prevalence of multimorbidity in the Canadian population aged 20 years and above was in a large part due to the ageing population. Similar to Roberts et al., I found multimorbidity is significantly associated with being female, older, poor, stressed, obese, a smoker, and physically inactive. Next, I suggest that managing multimorbidity will require that the health care authorities keep working towards implementing integrated health care models and preventing multimorbidity will require the government to keep working towards improving social programs.

## LITERATURE REVIEW

### Defining multimorbidity

The notion of multimorbidity first emerged in the 1970s (Brandlmeier, 1976) as a supplement to comorbidity, which is defined as occurrence of health conditions or diseases in addition to an index disease (van den Akker et al., 1996). Although used interchangeably in the past, there are important distinctions between the terms “comorbidity” and “multimorbidity”. Multimorbidity describes the “coexistence of two or more chronic diseases in the same individual”, in which no one disease is designated the index disease (van den Akker et al., 1996; Boyd and Fortin, 2010). However, to date, there is no consensus or a clear definition on the types of diseases or health impairments constituting multimorbidity (Tetzlaff et al., 2017). Generally, the higher the number of diseases included in set of chronic diseases defining multimorbidity, the higher the prevalence of multimorbidity (Boyd and Fortin, 2010).

To assess multimorbidity, some researchers have used simple counts of chronic diseases, while others have included symptoms (e.g., back pain) and/or risk factors (e.g., obesity) in the definition or combined quantity and severity of diseases by applying weighted index measures (Willadsen et al., 2016). If only a simple count of chronic diseases is used, the minimum number of diseases required to define multimorbidity requires further consideration. If the cut-off is laid at two diseases, high prevalence rates may be obtained, particularly in the older age groups. Hence, assessing multimorbidity using a cut-off of two diseases as well as three diseases may be more useful (Fortin et al., 2012; Tetzlaff et al., 2017). Despite the lack of a consistent definition, monitoring multimorbidity in the population is important for researchers and policy makers because it has been linked with negative health outcomes and increased health care utilization and costs (Fortin et al., 2007; Glynn et al., 2011).

## The challenge of multimorbidity

The problems and risks associated with multimorbidity can significantly decrease the quality of life for a patient (Fortin et al., 2006; Fortin et al., 2007b; Kanesarajah et al., 2018). Generally, the degree of physical and social disability rises with the number of medical conditions a patient has (van den Akker et al., 1996; Garin et al., 2014). Moreover, multimorbidity is also associated with reduced life expectancy and an increased risk of developing further mental health conditions (Menotti et al., 2001; Arokiasamy et al., 2015). These factors create additional health care needs for the patient, including increased primary care consultations, repeated referrals for specialized care, increased and unplanned hospital admissions, longer stay in hospitals, complex self care needs and additional treatment issues such as polypharmacy<sup>1</sup>, which further increase the risk of adverse drug events due to interactions between drugs and adverse effects of drugs used for one disease on other diseases (Glynn et al., 2011; Payne et al., 2013; Specogna et al., 2017; Fortin et al., 2007; Watt, 2017; Calderón-Larrañaga et al., 2012).

For physicians, these factors increase the clinical complexity of caring for patients with multimorbidity, even though patients with multimorbidity constitute the majority of consultations for primary care physicians. A Canadian study that included 980 adult patients consulting in primary care setting found that 9 out of 10 patients had multimorbidity (Fortin et al., 2005). Given that the clinical guidelines are based on a single disease paradigm, potentially conflicting recommendations may be presented thereby further compromising the health of patients with multimorbidity (Dawes, 2010; van Weel & Schellevis, 2006).

Multimorbidity can also have an impact on patients' family and friends as caring for the patient may require a lot of time and energy, and, in some cases, a considerable change in

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<sup>1</sup> Polypharmacy refers to the simultaneous use of multiple drugs by a single patient, for one or more conditions.

lifestyle (van den Akker et al., 1996). For society as a whole, multimorbidity causes an increased need for social and health care services and a loss of productivity (van den Akker et al., 1996; Glynn et al., 2011, Holden et al., 2011).

Because of the problems and serious consequences of multimorbidity for the patient, family and friends, health care providers and society as a whole, it is important to gain further insight into the prevalence and the determinants of multimorbidity.

### Global patterns of multimorbidity

Prevalence estimates of multimorbidity within the same countries vary due to diverse data collection methods, sources of data, target populations and number and types of diseases considered for defining multimorbidity.

In the United States (US), a cross-sectional study<sup>2</sup> conducted in the primary care setting among practices in 43 states reported two or more chronic diseases (2+ chronic diseases) prevalence rate of 45.2% and three or more chronic diseases (3+ chronic diseases) prevalence rate of 30.3% among those aged 18 years and over (Ornstein et al., 2013). However, it is important to note that studies measuring prevalence rates in primary care tend to be overrepresented by patients who see their physician often because of multiple conditions (Fortin et al., 2010). Ornstein et al. (2013) also determined that prevalence of multimorbidity increased significantly and steeply with age, levelling off at age 80, but was similar among men and women at the same age.

Another study conducted using a general population survey in 2010 reported that prevalence of multimorbidity (2+ chronic diseases) increased significantly from 21.8% in 2001 to 26.0% in 2010 in the noninstitutionalized US population aged 18 years and over (Ward et al.,

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<sup>2</sup> A cross-sectional study is a type of observational study that analyzes data from a population, or a representative subset, at a specific point in time.

2013). The prevalence also increased significantly with age, was higher among women than men and among non-Hispanic white and non-Hispanic black adults than Hispanic adults.

Based on medical records of patients enlisted in primary care practices in Netherlands, Uijen and van de Lisdonk (2008) reported that proportion of patients with two chronic diseases increased from 6.7% to 8% between 1985 and 2005, while the proportion of those with three chronic diseases increased from 3% to 5%. They also found increasing age, female sex, and low socio-economic class were associated with an increasing number of patients with multimorbidity.

More recently, van Oostrom et al. (2016) used medical records of patients from primary care practices as well as national health interview surveys to examine the trends in the prevalence of multimorbidity (2+ chronic diseases) from 2001 to 2011 in the Netherlands, and the extent to which it can be ascribed to the ageing of the population. They reported an increase of multimorbidity prevalence from 12.7% to 16.2% using data from general practices and from 14.3% to 17.5% based on data from the surveys. Ageing of the population only explained part of these trends, implying that other factors such as health care and society-related developments substantially contribute to the rise in prevalence.

Dhalwani et al. (2016) used a longitudinal study<sup>3</sup> to assess trends of multimorbidity (2+ chronic diseases) and the association between multimorbidity and physical activity in a national representative cohort of the English population aged 50 and over between 2002 and 2013. They reported an overall increase in prevalence of multimorbidity from 31.7% in 2002/3 to 43.1% in 2012/13. While adjusting for variables previously associated with multimorbidity, the authors also reported a significant association between low levels of physical activity and multimorbidity. A summary of this section is available in Table 1.

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<sup>3</sup> A longitudinal study is an observational research method in which data is gathered for the same subjects repeatedly over a period of time.

**Table 1: Summary of global patterns of multimorbidity.**

Research Study	Country	Data Collection Setting	Age of Target Population	Multimorbidity Definition (# of chronic diseases)	Multimorbidity Prevalence
Ornstein et al., 2013	United States of America	Primary care	≥ 18 years	2 or more	45.2%
				3 or more	30.3%
Ward et al., 2013	United States of America	General population	≥ 18 years	2 or more	(From 2001-2010) 21.8% - 26.0%
Uijen and van de Lisdonk, 2008	Netherlands	Primary care	≥ 0 years	2	(From 1985-2005) 6.7% - 8%
				3	3% - 5%
				4 or more	2.6% - 7.5%
Van Oostrom et al., 2016	Netherlands	Primary care	≥ 25 years	2 or more	(From 2004-2011) 12.7% - 16.2%
		General population	≥ 25 years	2 or more	(From 2001-2011) 14.3% - 17.5%
Dhalwani et al., 2016	United Kingdom	General population	≥ 50 years	2 or more	(From 2002-2013) 31.7%-43.1%

### Patterns of multimorbidity in Canada

Similar to other countries, estimates of prevalence of multimorbidity within Canada vary across literature from 4% to over 90% due to dissimilar study designs and definitions of multimorbidity (Fortin et al., 2005; Fortin et al., 2010; Kuwornu et al., 2014; Agborsangaya et al., 2012; Pefoyo et al., 2015; Roberts et al., 2015).

Fortin et al. (2005) estimated the prevalence of multimorbidity in primary care patients by counting the number of medical conditions and using a measure that considers the severity of the medical conditions. Using data obtained from the Saguenay region of Quebec, Canada, where the socio-economic status of residents is comparable to that of those in the rest of Canada, the prevalence of having 2+ chronic diseases in those aged 18-44 years, 45-64 years and 65 years and over was estimated at, respectively, 68%, 95%, and 99% among women and 72%, 89%, and 97% among men. The mean number of medical conditions and the mean severity of those conditions

increased significantly with age. As mentioned previously, prevalence rates in primary care studies tend to be overrepresented by patients who see their physician often because of multiple conditions. This was shown by Fortin et al. (2010) in a study where they observed an overall multimorbidity (2+ chronic diseases) prevalence of 11.6% in the general population and 32.3% in the primary care population, using data obtained from adults aged 25 years and over in the province of Quebec. Moreover, prevalence estimates were considerably higher for each age group in the primary care sample than in the general population.

Agborsangaya et al. (2012) used data from the 2010 Health Quality Council of Alberta Patient Experience Survey to report an overall age and sex standardized multimorbidity (2+ chronic diseases) prevalence rate of 19% among a representative sample of those aged 18 years and over in Alberta. They also reported that being female, older age, lower household income and not living with children aged 16 years or younger were risk factors associated with elevated odds of having multimorbidity. Stratification by age revealed that annual household income less than \$100,000 and those not living with children aged 16 years or younger were significantly more likely to have multimorbidity among those aged 25-44 years. Among those aged 45-64 years, multimorbidity was significantly more likely among females, those with an annual household income less than \$100,000 and those not living with children aged 16 years or younger. Among those aged 65 years and over, multimorbidity was significantly more common among females and those not living with children aged 16 years or younger. Later, Agborsangaya et al. (2013) also showed that obesity was significantly associated with multimorbidity.

Pefoyo et al. (2015) conducted a retrospective cohort study using linked provincial health administrative databases to estimate prevalence of multimorbidity in Ontarians aged 0 to 105 years in 2003 and 2009. The prevalence of 2+ chronic diseases rose from 17.4% in 2003 to 24.3% in

2009. Similarly, the prevalence of 3+ chronic diseases nearly doubled between 2003 and 2009. This increase in prevalence over time was evident across all age groups.

Similarly, Rosella et al. (2018) conducted a retrospective cohort study using multiple linked population files and health administrative data to estimate the trend in prevalence of multimorbidity (2+ chronic diseases) at the time of death from 1994 to 2013 in Ontario. The prevalence of multimorbidity at death increased from 79.6% in 1994 to 95.3% in 2013. The increase in prevalence at death was observed across all age groups. They also noted that chronic respiratory diseases and diabetes were disproportionately represented among those living in neighbourhoods with low-income and greater material deprivation.

Kuwornu et al. (2014) used data from the 2005 CCHS to compare prevalence of multimorbidity (2+ chronic diseases) in the Aboriginal population with the matched (by sex and age) non-Aboriginal Caucasian population. The Aboriginal respondents reported a prevalence rate of 38.9% compared to 30.7% of non-Aboriginal Caucasian respondents.

Roberts et al. (2015) used the 2011/12 CCHS to report that 12.9% of Canadians aged 20 years and older had 2+ chronic diseases and 3.9% had 3+ chronic diseases. Among the socio-economic determinants, being female, older, Aboriginal and living in the lowest income quintile were significantly associated with having 3+ chronic diseases. Among the health and behavioural risk factors, physical inactivity, being a smoker, having high stress and being obese were significantly associated with having 3+ chronic diseases. Stratification by age revealed that poverty, obesity and high stress levels were significantly associated with multimorbidity (3+ chronic diseases) among all age groups. In addition, in the 35-49 year age group, being a smoker was significantly associated with multimorbidity. Among those aged 50-64 years, being female, Aboriginal, physical inactivity and being a smoker were also significantly associated with

multimorbidity. Among those aged 65 years and over, being Aboriginal and physical inactivity were also significantly associated with multimorbidity.

Overall, the literature review revealed that there is limited population-based information about multimorbidity in Canada (Roberts et al., 2015). A few population-based studies have been conducted for individual provinces (Fortin et al., 2010; Agborsangaya et al., 2012; Pefoyo et al., 2015); however, only one of these have examined time trends in prevalence of multimorbidity (Pefoyo et al., 2015). A summary of this section is available in Table 2.

**Table 2: Summary of patterns of multimorbidity in Canada.**

<b>Research Study</b>	<b>Region</b>	<b>Data Collection Setting</b>	<b>Age of Target Population</b>	<b>Multimorbidity Definition (# of chronic diseases)</b>	<b>Multimorbidity Prevalence</b>
Fortin et al., 2005	Saguenay Region, Quebec	Primary care	18-44 years	2 or more	Female: 68% Male: 72%
			45-64 years	2 or more	Female: 95% Male: 89%
			≥ 65 years	2 or more	Female: 99% Male: 97%
Fortin et al., 2010	Quebec	Primary care	≥ 25 years	2 or more	32.3%
		General population	≥ 25 years	2 or more	11.6%
Agborsangaya et al., 2012	Alberta	General population	≥ 18 years	2 or more	19%
Pefoyo et al., 2015	Ontario	Primary care	0-105 years	2 or more	(From 2003-2009) 17.4% - 24.3%
Rosella et al., 2018	Ontario	Multimorbidity at death	≥ 18 years	2 or more	(From 1994-2013) 79.6% - 95.3%
Kuwornu et al., 2014	Canada	General population	≥ 18 years	2 or more	Aboriginal: 38.9% Non-Aboriginal Caucasian: 30.7%
Roberts et al., 2015	Canada	General population	≥ 20 years	2 or more	12.9%
				3 or more	3.9%

## RESEARCH PROBLEM

In 2016, for the first time, the proportion of Canadians aged 65 years and older (16.9%) exceeded the share of those aged 14 years and younger (16.6%) (Statistics Canada, 2016). Moreover, the proportion of senior Canadians increased by 20% from 2011 to 2016 whereas the overall population only increased by 5%. This recent acceleration in population ageing is due in part to baby boomers getting older, but also due to two other trends – longer life expectancies and lower fertility rates (Statistics Canada, 2016).

As shown in previous studies (Agborsangaya et al., 2012; Roberts et al., 2015), the prevalence of multimorbidity steeply increases with age. Despite the expected increase in prevalence of multimorbidity over time due to an ageing population, there is a lack of research in this area, specifically national, population-based studies depicting time trends in the prevalence of multimorbidity. To address the notable gaps in the literature and to contribute towards existing research, the purpose of this study is to:

- 1) estimate the trends in prevalence of multimorbidity from 2007-2013 in Canadian population aged 20 years and older; and,
- 2) replicate the study by Roberts et al. (2015) using a much larger sample by pooling data from 2007-2013 to assess the overall and stratified by age group association of socio-economic determinants and health and behavioural risk factors with multimorbidity.

## METHODOLOGY

### Data Source: Canadian Community Health Survey

The study is based on data from the Canadian Community Health Survey (CCHS), which is a cross-sectional population health survey conducted by Statistics Canada to collect self-reported data regarding a range of measures related to health status, health care utilization and health determinants (Béland, 2002; Statistics Canada, 2016).

The target population of the survey includes Canadian population 12 years and over living in the ten provinces and the three territories. The CCHS excludes people living in nursing homes, long-term care facilities or on reserves. It also excludes full-time members of the Canadian Armed Forces and institutionalized population and persons living in Quebec's Région du Nunavik and Région des Terres-Cries-de-la-Baie-James. In Nunavut, the coverage is limited to the ten largest communities which represents about 70% of the Nunavut population. Altogether, these exclusions represent less than 3% of the target population (Béland, 2002; Statistics Canada, 2007).

For the purpose of the CCHS, each province is divided into health regions, and each territory is designated as a single health region. The sample allocation strategy consists of three steps. The first two steps of the strategy allocate sample size among the provinces and territories according to their respective populations and the number of health regions they contain. In the third step, each province's sample is allocated among its health regions proportionally to the square root of the estimated population in each health region. This multi-stage sample allocation strategy ensures relatively equal weighting to the health regions and the provinces (Béland, 2002; Statistics Canada, 2016).

Furthermore, the CCHS uses three sampling frames to select the sample of households: the majority of the sample of households come from an area frame designed for Canadian Labour

Force Survey and remaining are selected from a list frame of telephone numbers and from a Random Digit Dialling sampling frame. Sample units selected from the area frame are interviewed using the Computer-Assisted Personal Interviewing (CAPI) method while units selected from the telephone list frames and Random Digital Dialling are interviewed using the Computer-Assisted Telephone Interviewing (CATI) method (Béland, 2002; Statistics Canada, 2016).

Taking into account the sample design, each respondent is assigned a weight to represent his or her contribution to the total population by employing estimation techniques from survey sampling theory. Further details about the CCHS methodology are described by Béland (2002) and are available on Statistics Canada's website.

### Pooling the CCHS cycles together

For the purpose of this study, I used the CCHS Public Use Micro Files (PUMFs), which are prepared by Statistics Canada using the CCHS master files to protect the anonymity of individual survey respondents. The CCHS PUMFs from different years were pooled together to: 1) study trends in prevalence of multimorbidity over time in Canada, and 2) obtain a large sample to allow for a robust analysis to determine the association of socio-economic and health and behavioural risk factors and multimorbidity. As the CCHS has evolved over time, pooling the PUMFs together required considering changes in coverage, including changes in the target population and sample size, from cycle to cycle (Thomas & Wannell, 2009). Moreover, changes in the content of the survey, including the wording of the questions and response categories, were also considered.

The CCHS was initiated in 2000 and initially collected data every two years from approximately 130,000 respondents; however, the 2000 and 2003 cycles were not used in this study as they do not capture data for some of chronic diseases that are being used to determine

multimorbidity. The 2005 cycle was not used as it measures total household income in a distinct manner compared to the other cycles. Starting from 2007, although the CCHS data was collected every year from approximately 65,000 respondents, PUMFs were prepared by combining two years of data (for example, 2007-2008, 2009-2010, etc.) (Statistics Canada, 2016). Hence, for the purpose of this study, I pooled together the CCHS PUMFs from, 2007-2008, 2009-2010, 2011-2012 and 2013-2014 each with a sample size of 130, 000 (referred to from this point onwards as 2007, 2009, 2011, and 2013).

The CCHS content is comprised of four components. The analysis reported on here only uses variables that are part of the core component of the CCHS, which includes questions that are asked of all respondents and remain stable over time, to ensure that results are relevant and interpretable (Béland, 2002; Statistics Canada, 2016).

### Dependent Variable: Presence of Multimorbidity

In the CCHS, participants were asked the following questions to identify chronic conditions: “Remember, we’re interested in conditions diagnosed by a health professional and that are expected to last or have already lasted 6 months or more. Do you have [...]?” The response categories included: ‘YES’, ‘NO’, ‘Don’t know’ and ‘Refusal’.

This study defines two measures of multimorbidity: having two or more (2+) and three or more (3+) chronic diseases. This definition is based on the guidelines that Roberts et al. (2015) used based on the work by an expert working group convened by the Public Health Agency of Canada in 2012. Based on the criteria established by the working group and data availability in the CCHS PUMFs, eight different chronic conditions will be taken into account in this study to determine the prevalence of multimorbidity: asthma, arthritis, chronic obstructive pulmonary disease (COPD), diabetes mellitus, heart disease, mental disorder (mood disorder and/or anxiety),

cancer and side-effects of stroke. Roberts et al. had also included Alzheimer's disease and related dementias as another chronic disease; however, data for these conditions is only available in the CCHS master files held by Statistics Canada.

### Independent Variables: Year, Socio-economic and Health and Behavioural Risk Factors

Based on previously identified socio-economic determinants and health and behavioural risk factors associated with multimorbidity (Agborsangaya et al., 2012; Roberts et al., 2015), this study will re-assess the association using a larger sample obtained from pooling the CCHS PUMFs together. The study will consider the following socio-economic factors:

- 1) Age (20-34 years, 35-49 years, 50-64 years vs.  $\geq 65$  years);
- 2) Sex (female vs. male);
- 3) Total household income (< \$20,000, \$20,000-\$39,000, \$40,000-\$59,000; \$60,000-\$79,000 vs.  $\geq$  \$80,000);
- 4) Highest education level attained in the household (less than high school; high school completed; some post-secondary education vs. post-secondary education completed);  
and,
- 5) Immigration status (immigrant and lived in Canada < 10 years, immigrant and lived in Canada  $\geq 10$  years vs. Canadian born).

Similar to Roberts *et al.* (2015), this study will consider the following health and behavioural risk factors:

- 1) High blood pressure;
- 2) Obesity (recoded to 'Yes' when body mass index  $\geq 30$  based on self-reported information);

- 3) High Stress (recoded to 'Yes' when a respondent perceived their life stress as "quite a bit" or "extremely" and recoded to 'No' when a respondent perceived their life stress as "not at all", "not very" or "a bit");
- 4) Physical activity (recoded to 'Yes' when the respondent answered "active" or "moderate active" and recoded to 'No' when the respondent answered "inactive")
- 5) Being a smoker (recoded to 'Yes' when the respondent answered "daily", "occasional" or "always occasionally" and recoded to 'No' when the respondent answered "former daily", "former occasional" or "never smoker"); and,
- 6) Consumption of less than 5 fruits and vegetables per day.

## Data Analysis

I used the 'survey' package in the R software to account for the complex survey design of CCHS while conducting data analysis. I conducted descriptive analysis to examine prevalence of multimorbidity (2+ and 3+ chronic diseases) by year, socio-economic determinants and health and behavioural risk factors.

Next, I conducted univariate regression analysis to estimate the trends in prevalence rates of multimorbidity (2+ and 3+ chronic diseases) from 2007-2013 in the Canadian population aged 20 years and over. I also used multivariate logistic regression analysis to determine if the change in prevalence of multimorbidity was due an ageing population. Furthermore, I used multivariate logistic regression analysis to estimate associations of socio-economic and health and behavioural risk factors with multimorbidity.

Last, I used multivariate logistic regression analyses stratified by age groups to account for effect modification, which occurs when the magnitude of association between multimorbidity and risk factors may differ depending on the age of the individual.

## FINDINGS WITH DISCUSSION

### Descriptive Analysis: Prevalence of multimorbidity over time and distribution of multimorbidity by demographics and risk factors

The prevalence of 2+ chronic diseases in Canadians aged 20 years and over increased from 11.8% in 2007 to 12.6% in 2013. Similarly, the prevalence of 3+ chronic diseases in Canadians aged 20 years and over increased from 3.6% in 2007 to 3.9% in 2013 (Table 3).

**Table 3: Weighted prevalence of multimorbidity<sup>a</sup> overtime (CCHS 2007-2013, population aged ≥ 20 years)**

Year	Sample size, n	Prevalence of 2+ chronic diseases, % (95% CI) <sup>b</sup>	Prevalence of 3+ chronic diseases, % (95% CI) <sup>b</sup>
2007	116,569	11.8 (11.6-12.1)	3.6 (3.5-3.8)
2009	109,712	11.9 (11.6-12.2)	3.6 (3.5-3.8)
2011	111,176	12.7 (12.4-13.0)	3.8 (3.6-4.0)
2013	114,277	12.6 (12.3-13.0)	3.9 (3.7-4.1)
2007-2013	451,734	12.3 (12.3-12.3)	3.7 (3.7-3.7)

**Abbreviations:** CCHS, Canadian Community Health Survey; CI, confidence interval

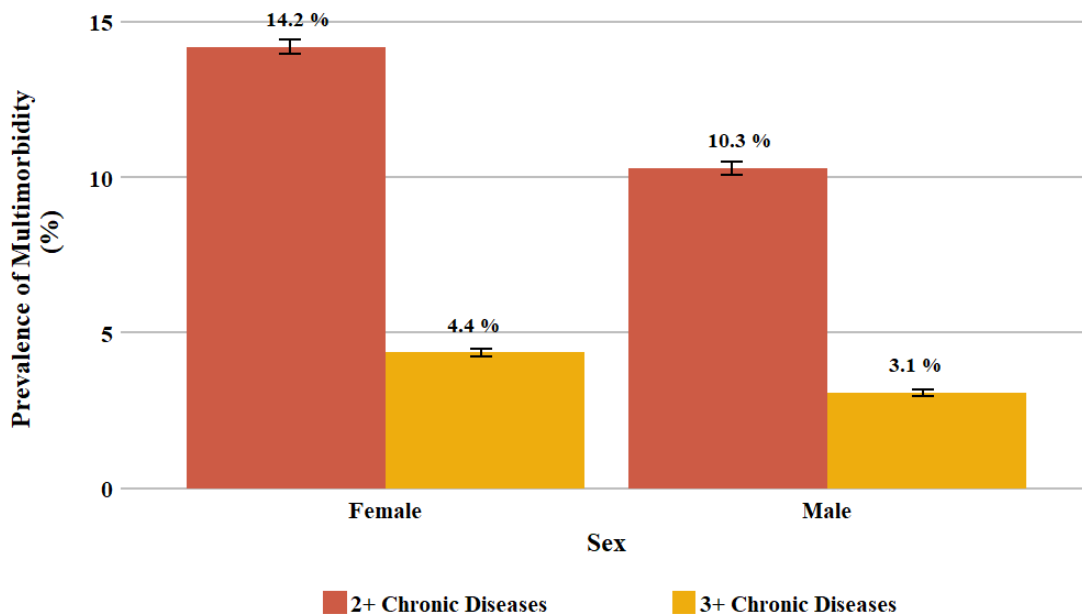
<sup>a</sup> Multimorbidity defined as 2 or more or 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> 95% confidence interval is a Wald-type interval.

The prevalence of multimorbidity is higher in females, older Canadians, those with low household income, those living in households where the highest education attained was less than high school and those born in Canada (Figures 1-5).

Moreover, the prevalence of multimorbidity is higher among those with high blood pressure, high stress and those who are obese, inactive, smoke and consume fewer than five servings of fruits and vegetables per day (Figure 6).

**Figure 1: Prevalence of multimorbidity<sup>a</sup> by gender (CCHS 2007-2013, population aged  $\geq 20$  years)**

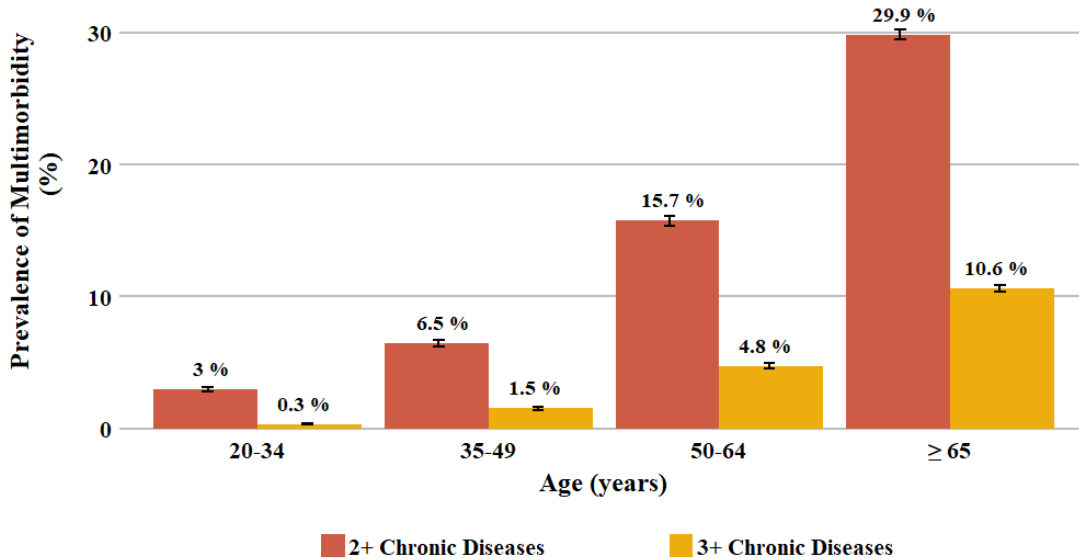


**Abbreviations:** CCHS, Canadian Community Health Survey

<sup>a</sup> Multimorbidity defined as 2 or more or 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

**Note:** Error bars represent 95% Wald-type confidence intervals.

**Figure 2: Prevalence of multimorbidity<sup>a</sup> by age (CCHS 2007-2013, population aged ≥ 20 years)**

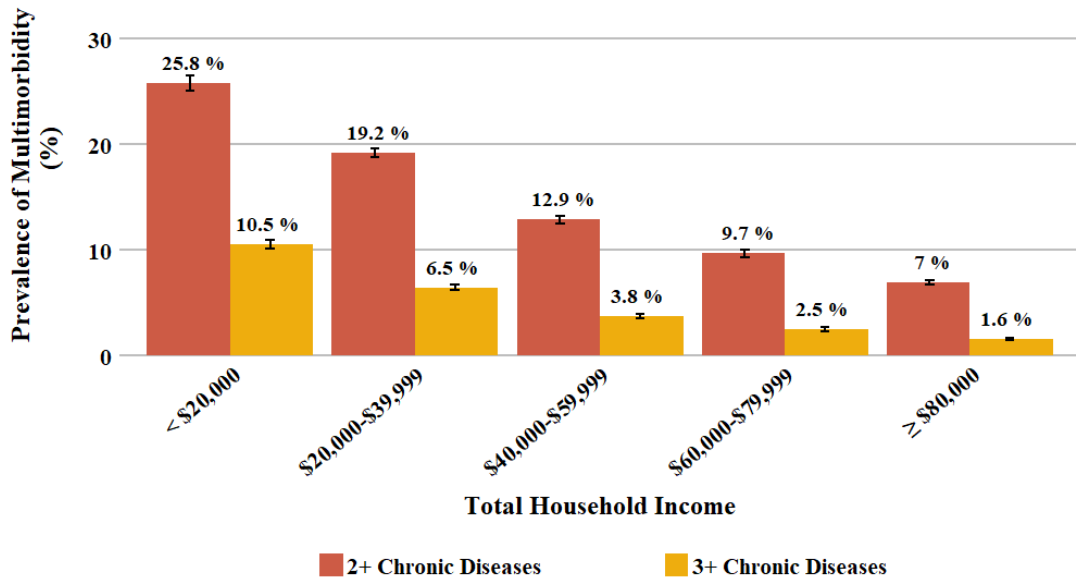


**Abbreviations:** CCHS, Canadian Community Health Survey

<sup>a</sup> Multimorbidity defined as 2 or more or 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

**Note:** Error bars represent 95% Wald-type confidence intervals.

**Figure 3: Prevalence of multimorbidity<sup>a</sup> by total household income (CCHS 2007-2013, population aged ≥ 20 years)**

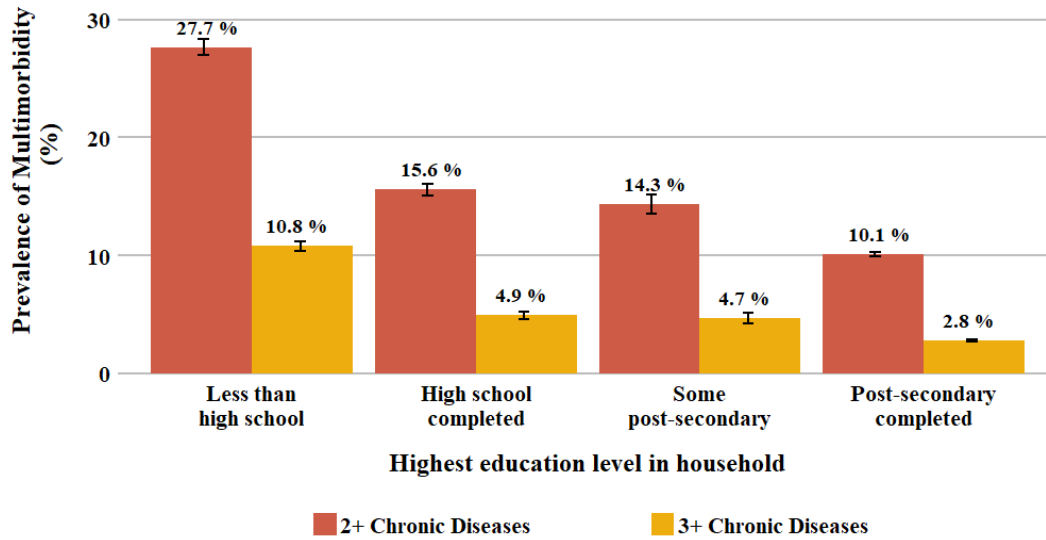


**Abbreviations:** CCHS, Canadian Community Health Survey

<sup>a</sup> Multimorbidity defined as 2 or more or 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

**Note:** Error bars represent 95% Wald-type confidence intervals.

**Figure 4: Prevalence of multimorbidity<sup>a</sup> by highest education level attained in household (CCHS 2007-2013, population aged ≥ 20 years)**

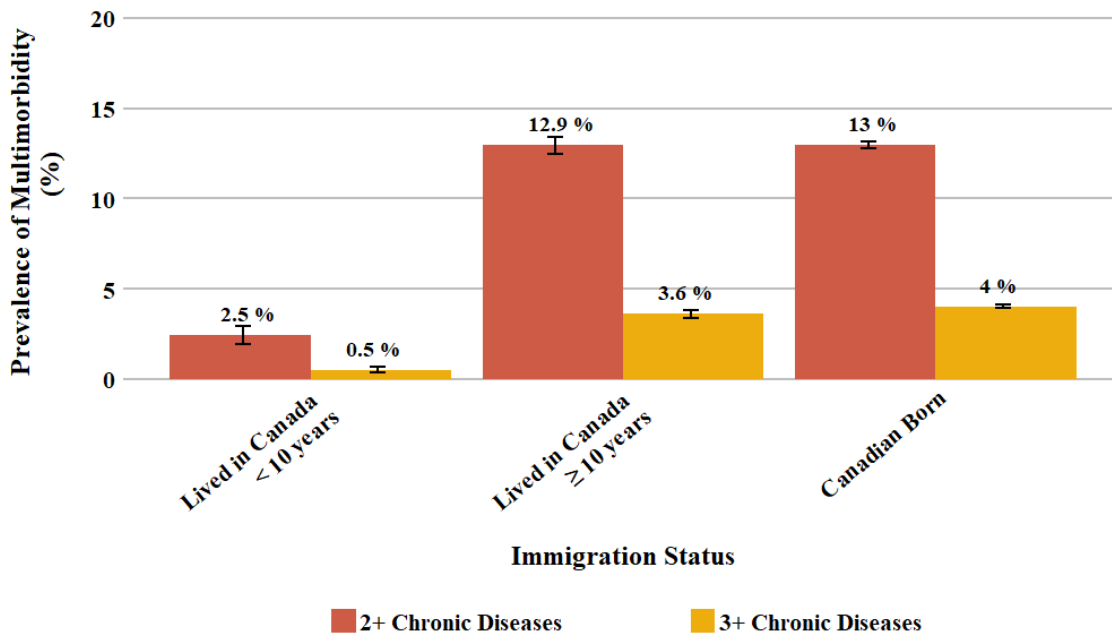


**Abbreviations:** CCHS, Canadian Community Health Survey

<sup>a</sup> Multimorbidity defined as 2 or more or 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

**Note:** Error bars represent 95% Wald-type confidence intervals.

**Figure 5: Prevalence of multimorbidity<sup>a</sup> by immigration status (CCHS 2007-2013, population aged ≥ 20 years)**

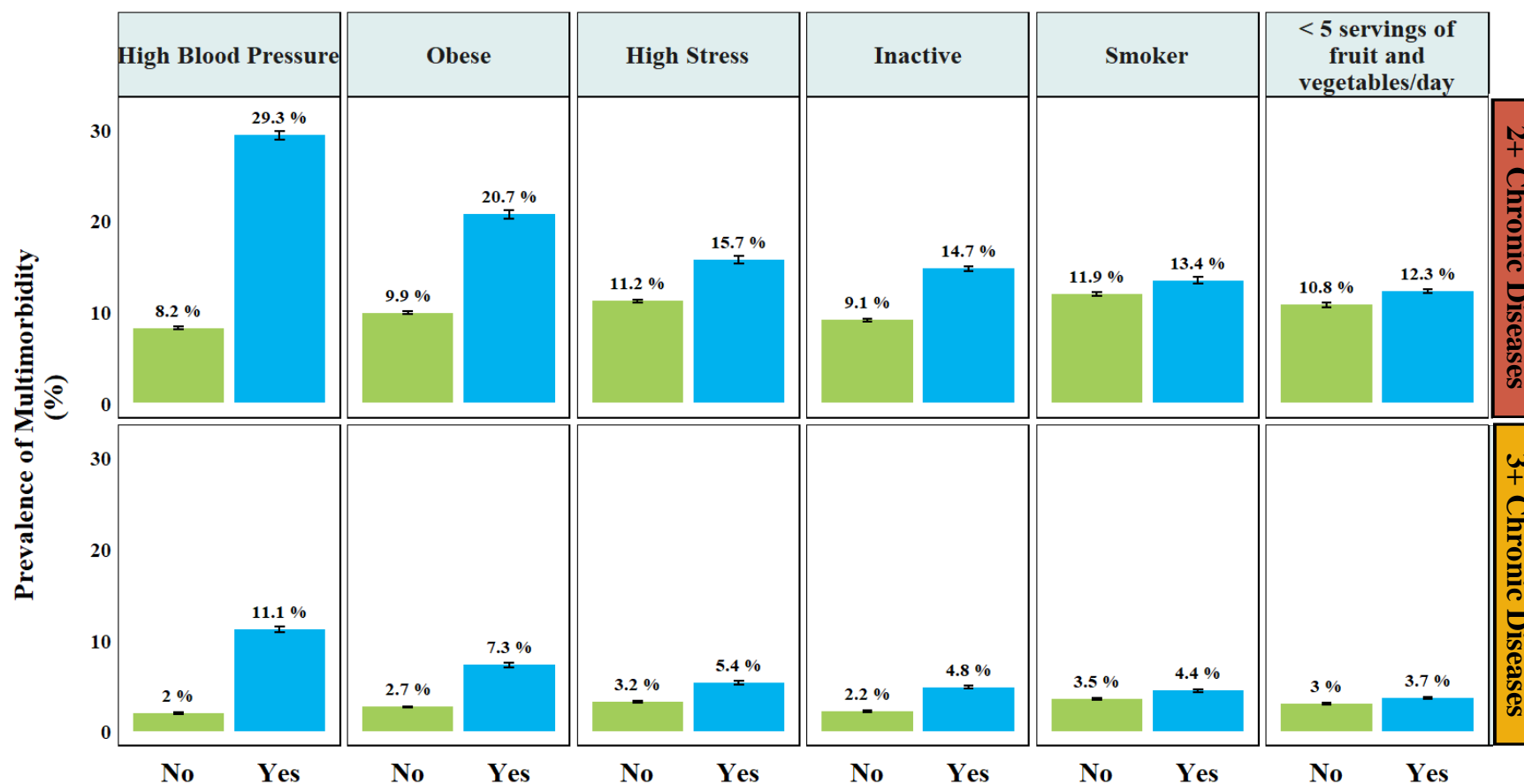


**Abbreviations:** CCHS, Canadian Community Health Survey

<sup>a</sup> Multimorbidity defined as 2 or more or 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

**Note:** Error bars represent 95% Wald-type confidence intervals.

Figure 6: Prevalence of multimorbidity<sup>a</sup> by health and behavioural risk factors (CCHS 2007-2013, population aged ≥ 20 years)



**Abbreviations:** CCHS, Canadian Community Health Survey

<sup>a</sup> Multimorbidity defined as 2 or more or 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

**Note:** Error bars represent 95% Wald-type confidence intervals.

Other descriptive analysis, such as prevalence of each chronic condition in the population and most common disease dyads and triads in those with multimorbidity, has been added in the appendices in Tables A1-3.

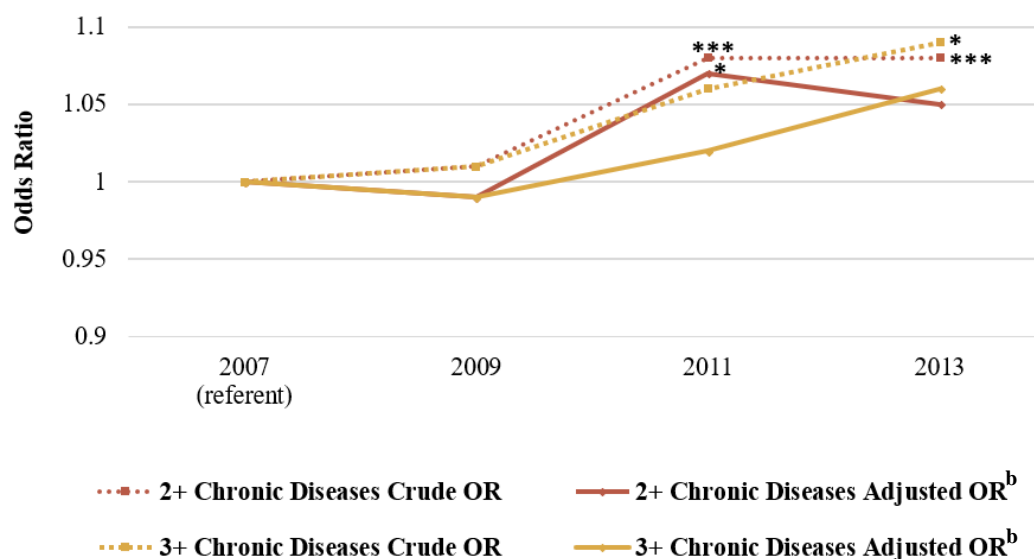
### Regression Analysis: Prevalence of multimorbidity over time from 2007- 2013

I used univariate regression analysis to reveal that in comparison to 2007, the increase in prevalence of 2+ chronic diseases was significant in 2011 and 2013. For 3+ chronic diseases, increase in prevalence was significant in 2013 (in comparison to 2007) (Figure 7). These findings are in alignment with Pefoyo et al. (2015) as their study also reported an increase in prevalence of multimorbidity in Ontario from 2003 to 2009.

Although multivariate logistic regression analysis, which controlled for various factors including age, also revealed that in comparison to 2007, there is significant increase in prevalence of 2+ chronic diseases in 2011, the range of the odds ratio suggested that the increase was very minor (Appendices Table A4). The increase in prevalence of 3+ chronic diseases over time from 2007-2013 was not significant with multivariate logistic regression analysis. This suggests that the that the increase in prevalence of multimorbidity from 2005-2013 is for a large part due to an ageing population. These findings are in contrast to the study conducted by van Oostrom et al. (2016) in Netherlands, where they found that ageing of the population only explains part of the rise in prevalence of multimorbidity.

I further stratified my analysis by age to reveal that prevalence of 2+ chronic diseases increased significantly in the 20-34 years age group in 2011 (in comparison to 2007), although the range of the odds ratio suggested that the increase was very minor (Table 4). The increase in prevalence of 3+ chronic diseases from 2007 to 2013 was not significant for any of the age groups (Table 5).

**Figure 7: Prevalence of multimorbidity<sup>a</sup> over time (CCHS 2007-2013, population aged ≥ 20 years)**



**Abbreviations:** CCHS, Canadian Community Health Survey; OR, odds ratio; CI, confidence interval

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 2 or more or 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

**Table 4: Prevalence of multimorbidity<sup>a</sup> (2+ chronic diseases) by age (CCHS 2007-2013)**

Year	Adjusted OR (95% CI) <sup>b</sup> by age, years			
	20-34	35-49	50-64	≥ 65
2007 (referent)	1.0	1.0	1.0	1.0
2009	0.9 (0.8-1.1)	1.0 (0.8-1.1)	1.0 (0.9-1.1)	1.0 (1.0-1.1)
2011	1.2 * (1.0-1.5)	1.0 (0.9-1.2)	1.1 (1.0-1.2)	1.1 (1.0-1.1)
2013	1.2 (1.0-1.4)	1.1 (0.9-1.2)	1.0 (0.9-1.1)	1.0 (1.0-1.1)

**Abbreviations:** CCHS, Canadian Community Health Survey; OR, odds ratio; CI, confidence interval

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 2 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

**Table 5: Prevalence of multimorbidity<sup>a</sup> (3+ chronic diseases) by age (CCHS 2007-2013)**

Year	Adjusted OR (95% CI) <sup>b</sup> by age, years			
	20-34	35-49	50-64	≥ 65
2007 (referent)	1.0	1.0	1.0	1.0
2009	1.0 (0.6-1.7)	0.9 (0.7-1.2)	0.9 (0.8-1.1)	1.1 (1.0-1.2)
2011	1.2 (0.7-1.9)	1.1 (0.8-1.4)	0.9 (0.8-1.1)	1.1 (1.0-1.2)
2013	0.7 (0.4-1.0)	1.2 (0.9-1.5)	1.1 (0.9-1.2)	1.0 (1.0-1.1)

**Abbreviations:** CCHS, Canadian Community Health Survey; OR, odds ratio; CI, confidence interval

<sup>a</sup> Multimorbidity defined as 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

### Regression Analysis: Determinants of multimorbidity

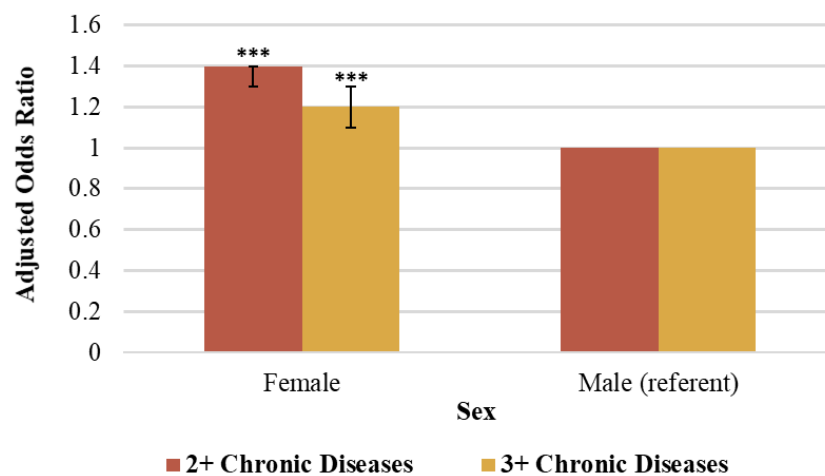
Similar to the findings of Roberts et al. (2015), after adjusting for all variables in the model, I found that multimorbidity (2+ chronic diseases and 3+ chronic diseases) was significantly associated with being female, older, poor, stressed, obese, a smoker, and physically inactive (Figures 8-10 and 12 and Appendices Table A4). Since the odds of having multimorbidity in the ≥ 65 age group are very high, regression analysis was repeated with the ≥ 65 age group segmented further. Through this, I found that multimorbidity steeply and significantly increases with age (Appendices Table A5).

I also found that higher levels of education in household did not diminish the risk of multimorbidity in the population as a whole (Appendices Table A4). Consumption of less than 5

servings of fruits and vegetables/day was only significantly associated with 2+ chronic diseases. In comparison to Roberts et al., I was also able to establish a significant association between having high blood pressure and multimorbidity (Figure 12 and Appendices Table A4). This is likely due to having a bigger sample size by pooling CCHS survey cycles together.

I also found that immigrants who have lived in Canada for less than 10 years are significantly less likely to be multimorbid, compared to those who are Canadian-born. Although immigrants who have lived in Canada for 10 years or longer had prevalence rates closer to those who are Canadian-born, they were still significantly less likely to have multimorbidity (Figure 11 and Appendices Table A4). These findings are in alignment with previous studies indicating that newly arrived immigrants are healthier than Canadian population, but over time there is a decline in this ‘healthy immigrant effect’ (Kennedy et al., 2015; Gushulak et al., 2011).

**Figure 8: Analysis of the association between sex and multimorbidity<sup>a,b</sup> (CCHS 2007-2013, population aged  $\geq 20$  years)**



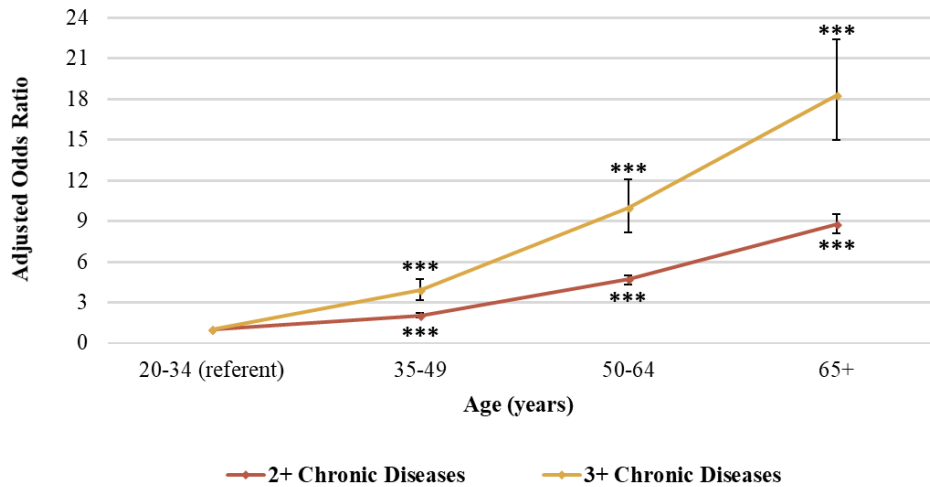
**Abbreviations:** CCHS, Canadian Community Health Survey

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 2 or more or 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

**Figure 9: Analysis of the association between age and multimorbidity<sup>a,b</sup> (CCHS 2007-2013, population aged ≥ 20 years)**



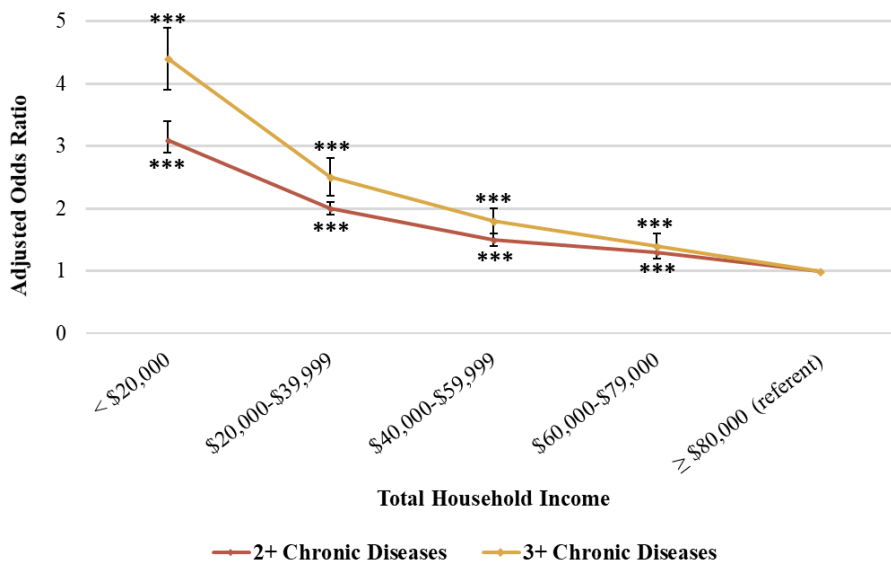
**Abbreviations:** CCHS, Canadian Community Health Survey

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 2 or more or 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

**Figure 10: Analysis of the association between household income and multimorbidity<sup>a,b</sup> (CCHS 2007-2013, population aged ≥ 20 years)**



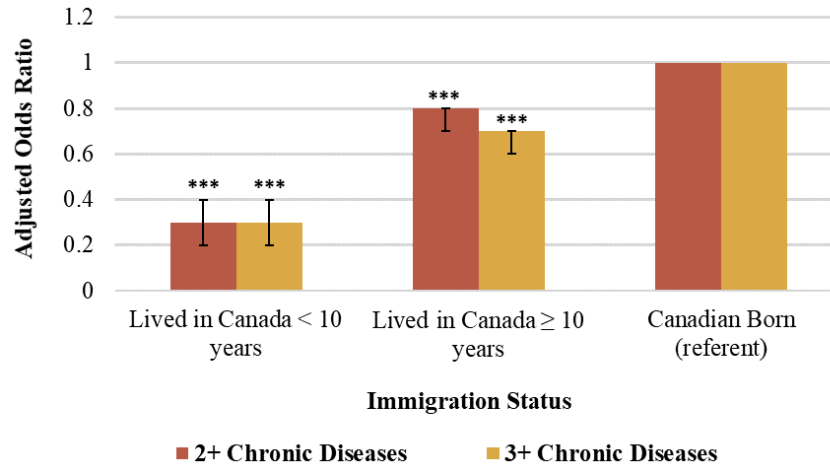
**Abbreviations:** CCHS, Canadian Community Health Survey

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 2 or more or 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

**Figure 11: Analysis of the association between immigration status and multimorbidity<sup>a,b</sup> (CCHS 2007-2013, population aged ≥ 20 years)**



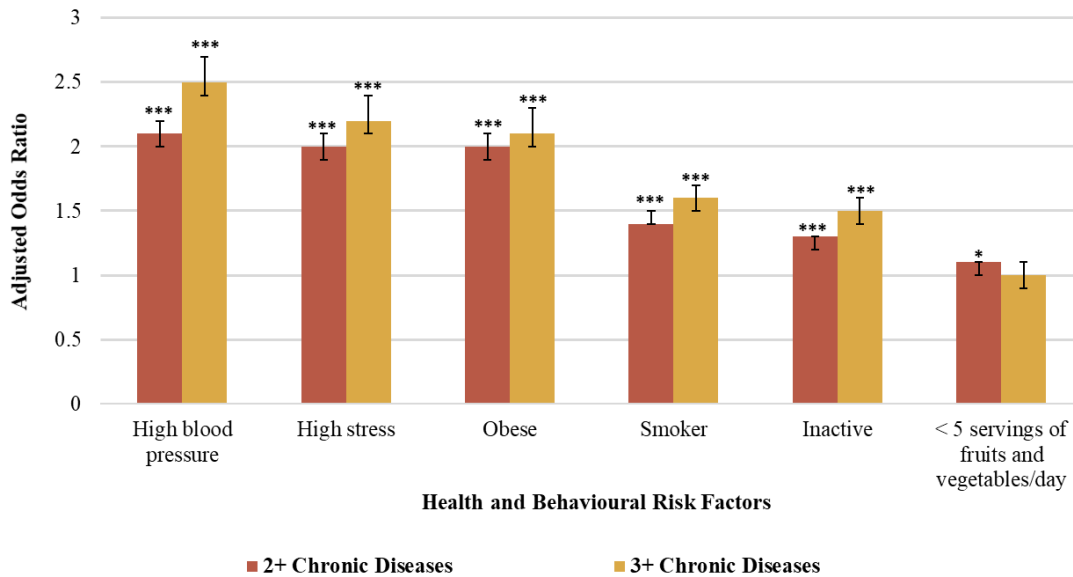
**Abbreviations:** CCHS, Canadian Community Health Survey

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 2 or more or 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

**Figure 12: Analysis of the association between health and behavioural risk factors and multimorbidity<sup>a,b</sup> (CCHS 2007-2013, population aged ≥ 20 years)**



**Abbreviations:** CCHS, Canadian Community Health Survey

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 2 or more or 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

## Regression Analysis: Determinants of multimorbidity (3+ chronic diseases) by age groups

Among those aged 20 to 34 years, being female and poor were socio-economic factors significantly associated with multimorbidity. In the 25 to 49-year age group, being female, poor and highest household education level of less than high school (compared to post-secondary education completed) were significantly associated with multimorbidity. Being an immigrant, in comparison to a Canadian-born, was significantly associated with reduced odds of having multimorbidity. Among those aged 50 to 64 years, being female, poor, and highest household education level of less than high school were significantly associated with multimorbidity. Being an immigrant once again was significantly associated with reduced odds of having multimorbidity. In those aged 65 years and over, being poor was significantly associated with increased odds of having multimorbidity whereas being an immigrant who has lived in Canada 10 years or more was significantly associated with reduced odds of having multimorbidity (Tables 6-9).

Among the behavioural and health risk factors, I found that high blood pressure, high levels of stress, being obese and a smoker were significantly associated with multimorbidity for all age groups. Physical activity significantly contributed to the prevalence of multimorbidity for those aged 50 years and over. Consumption of less than 5 servings of fruits and vegetables/ day was significantly associated with multimorbidity for the 20-34 years age group (Table 10).

Of those with 2+ chronic conditions, I found that determinants of multimorbidity are very similar and are reported in appendices in Tables A6-10. The odds ratios reported in this study (Tables 6-10) are similar to the ones reported by Roberts et al. (2015). However, a bigger sample size by pooling the CCHS 2007-2013 cycles allows us to establish statistical significance where Robert et al. could not despite obtaining similar odds ratios. Thus, I provide evidence that differences in odds ratio are less likely to be due to chance.

**Table 6: Analysis of the association between gender and multimorbidity<sup>a</sup> (3+ chronic diseases) by age (CCHS 2007-2013)**

Sex	Adjusted OR (95% CI) <sup>b</sup> by age, years			
	20 -34	35-49	50-64	≥ 65
Female	1.8 ** (1.2-2.7)	2.2 *** (1.8-2.7)	1.4 *** (1.3-1.6)	0.9 (0.9-1.0)
Male (referent)	1.0	1.0	1.0	1.0

**Abbreviations:** CCHS, Canadian Community Health Survey; OR, odds ratio; CI, confidence interval

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

**Table 7: Analysis of the association between household income and multimorbidity<sup>a</sup> (3+ chronic diseases) by age (CCHS 2007-2013)**

Household Income	Adjusted OR (95% CI) <sup>b</sup> by age, years			
	20 -34	35-49	50-64	≥ 65
<\$20,000	5.6 *** (3.2-9.7)	7.3 *** (5.4-9.9)	5.9 *** (4.9-7.0)	2.1 *** (1.9-2.5)
\$20,000-\$39,999	3.4 *** (2.0-5.6)	2.8 *** (2.1-3.8)	2.9 *** (2.4-3.5)	1.5 *** (1.3-1.8)
\$40,000-\$59,999	2.8 ** (1.5-5.7)	2.1 *** (1.6-2.9)	1.7 *** (1.5-2.0)	1.2 ** (1.1-1.4)
\$60,000-\$79,000	1.4 (0.8-2.4)	1.3 (0.9-1.8)	1.2 *** (1.3-1.8)	1.1 (0.9-1.3)
\$80,000 and over (referent)	1.0	1.0	1.0	1.0

**Abbreviations:** CCHS, Canadian Community Health Survey; OR, odds ratio; CI, confidence interval

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

**Table 8: Analysis of the association between highest household education level and multimorbidity<sup>a</sup> (3+ chronic diseases) by age (CCHS 2007-2013)**

Highest Household Education	Adjusted OR (95% CI) <sup>b</sup> by age, years			
	20 -34	35-49	50-64	≥ 65
Less than high school	1.5 (0.8-2.6)	1.4 * (1.1-1.9)	1.3 *** (1.1-1.5)	1.1 (1.0-1.2)
High school completed	1.4 (0.8-2.2)	0.9 (0.7-1.2)	1.0 (0.9-1.2)	0.9 (0.8-1.0)
Some post-secondary	1.0 (0.6-1.8)	1.4 (0.9-2.1)	1.1 (0.9-1.5)	1.2 * (1.0-1.5)
Post-secondary completed (referent)	1.0	1.0	1.0	1.0

**Abbreviations:** CCHS, Canadian Community Health Survey; OR, odds ratio; CI, confidence interval

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

**Table 9: Analysis of the association between immigration status and multimorbidity<sup>a</sup> (3+ chronic diseases) by age (CCHS 2007-2013)**

Immigration Status	Adjusted OR (95% CI) <sup>b</sup> by age, years			
	20 -34	35-49	50-64	≥ 65
Lived in Canada <10 years	0.2 * (0.0-1.0)	0.1 *** (0.1-0.3)	0.4 * (0.2-0.8)	0.6 (0.3-1.3)
Lived in Canada ≥ 10 years	0.3 ** (0.1-0.7)	0.3 *** (0.2-0.5)	0.6 *** (0.5-0.7)	0.8 *** (0.71-0.9)
Canadian-born (referent)	1.0	1.0	1.0	1.0

**Abbreviations:** CCHS, Canadian Community Health Survey; OR, odds ratio; CI, confidence interval

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

**Table 10: Analysis of the association between health and behavioural risk factors and multimorbidity<sup>a</sup> (3+ chronic diseases) by age (CCHS 2007-2013)**

Risk Factors	Adjusted OR (95% CI) <sup>b</sup> by age, years			
	20 -34	35-49	50-64	≥ 65
High blood pressure	8.4 *** (4.7-15.1)	3.8 *** (3.0-4.7)	2.9 *** (2.6-3.2)	1.9 *** (1.8-2.1)
High stress	2.4 *** (1.7-3.4)	2.8 *** (1.8-2.6)	2.1 *** (1.9-2.4)	2.4 *** (2.2-2.6)
Obese	1.9 ** (1.3-2.8)	2.3 *** (1.9-2.9)	2.2 *** (1.9-2.4)	1.9 *** (1.8-2.1)
Smoker	2.4 *** (1.6-3.6)	2.1 *** (1.7-2.5)	1.6 *** (1.4-1.8)	1.2 *** (1.1-1.3)
Inactive	1.1 (0.7-1.7)	1.2 (1.0-1.5)	1.4 *** (1.3-1.6)	1.7 *** (1.6-1.9)
< 5 servings of fruit and vegetables/day	0.6 * (0.4-0.9)	1.2 (1.0-1.5)	1.0 (0.9-1.1)	1.0 (0.9-1.1)

**Abbreviations:** CCHS, Canadian Community Health Survey; OR, odds ratio; CI, confidence interval

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

## LIMITATIONS

It is important to note that lack of standardized and reliable methodology for identification of multimorbidity may have limited the strength of the statistical analysis, affecting both the estimates of trends in prevalence and the identification of determinants of multimorbidity. Moreover, I used a simple count of diseases and defined multimorbidity as having two or more

chronic diseases and three or more chronic diseases. A major limitation of this approach is that it does not distinguish between diseases combinations with statistically significant associations and those combination that occur simply by chance. To address this limitation, it may be useful in future studies to identify non-random associations between diseases (i.e., cluster diseases together) to determine the factors associated with multimorbidity (Prados-Torres et al., 2012). Moreover, while high blood pressure and obesity are identified as risk factors for multimorbidity, there is a risk of an endogeneity problem within the model. That is to say that these risk factors may be somewhat endogenous because they are linked to one or more of the chronic diseases that are inherent in the definition of multimorbidity. More research is required to ascertain to whether, and to what extent, in fact, obesity and high blood pressure are endogenous variables.

Furthermore, the definition of multimorbidity in this study does not consider the degree of multimorbidity, such as having three chronic diseases versus having six or seven. The study is also limited by not taking into consideration the severity of each of the chronic diseases.

A further limitation of the study is that the cross-sectional nature of the data prevents establishing a temporal relationship between the socio-economic determinants and health and behavioural factors and multimorbidity. Another limitation associated with the cross-sectional nature of the data is that exposures were assessed at one moment in time, which prevents taking in account the duration of exposures (e.g.: someone who has been smoking for 1 year vs. someone who has been smoking for 10 years).

The study is also limited to the chronic conditions that individuals were asked about as part of the CCHS and those that are based on self-reports. Surveyed individuals with one or none of the listed chronic conditions, who were counted as not having multimorbidity in this study, may have other chronic conditions not listed in the CCHS. Other conditions (such as mental disorder)

may be under-diagnosed and underreported. Moreover, as with all self-reported data, self-reported chronic disease status is subject to information bias due to under-reporting of diagnoses or forgetfulness and misinterpretation of questions (Gross et al., 1996). This may have resulted in underestimating the true prevalence of multimorbidity.

Furthermore, some individuals who report multimorbidity may be reporting a single chronic condition, e.g. heart disease and side effects of stroke, which may lead to overestimating the true prevalence of multimorbidity. Finally, while the use of population-based CCHS provides the opportunity to assess multimorbidity among those at risk, the generalizability is restricted to the household population aged 20 years and above.

Despite the limitations, to my knowledge, this study is the first study that uses a population-based data source to estimate the trends in prevalence of multimorbidity over time in Canada. Moreover, a larger sample size obtained by pooling the 2007-2013 CCHS survey cycles together allowed estimating the association of multimorbidity with socio-economic determinants and health and behavioural risk factors at a higher precision.

## **POLICY IMPLICATIONS**

### **Control Measures: Integrated Health Care**

The Canadian population is ageing and in this study I demonstrated that the growing prevalence of multimorbidity in Canada is largely the result of an ageing population. In turn, individuals with multimorbidity drive a growing demand for health care services (Glynn et al., 2011). Yet clinical care guidelines describing care of these patients are largely based on evidence from trials that applied interventions for single diseases and often exclude older individuals and individuals with multimorbidity (Zulman et al., 2011; Fortin et al., 2006). This leads to fragmented

health care, where every individual recommendation made for each disease by multiple care providers may be rational and evidence based, but the sum of all recommendations for an individual with multimorbidity is not (Wallace et al., 2015).

The need for integrated health care, defined as “the management and delivery of health services such that people receive a continuum of health promotion, health protection and disease prevention services, as well as diagnosis, treatment, long-term care, rehabilitation, and palliative care services through the different levels and sites of care within the health system and according to their needs” (WHO, 2013), to reduce fragmentation of care and better meet the needs of people with multimorbidity is well recognized. Despite the need, the delay in health care policy reform is not due to a lack of trying but rather due to barriers such as the interests of the governing provincial or territorial party, resistance from professional medical associations, forces such as fiscal crises, public opinion in regards to certain types of reforms, etc. (Lazar et al., 2013; Levesque et al., 2015).

Currently, different integrated health care models have been piloted across Canada to provide more coordinated care. For example, the Ministry of Health and Long-Term Care in Ontario announced a Health Links program in December 2012 to improve care coordination for patients living with multiple chronic conditions and complex needs (Health System Performance Research Network (HSPRN), 2016). The Health Links approach brings together health care providers, social service providers and other supports together to address each patient’s specific needs in a coordinated manner. The first set of 22 Health Links were initiated in late August 2013. An evaluation conducted by Salmon River Health Link suggested that there was a 31% decrease in emergency department visits and 51% decrease in length of stay in hospital for patients who received assistance from Health Links (O’Leary & Watson, 2016). The program was well received and expanded to 82 Health Links as of July 2016 (HSPRN, 2016).

Similarly, the Nova Scotia Health Authority gathered feedback from key stakeholders, including patients and health care providers, as well as drawing on existing research evidence to redesign an existing Integrated Chronic Care Service model in Nova Scotia to better address the needs of those living with multiple chronic conditions. The proposed integrated model of care incorporated different elements, such as “in depth assessment of multiple diagnoses and a multidimensional symptom profile, integration of care needs, coordination of treatment at the care, health system, and community levels” (Sampalii et al., 2012) to enable both the patient and their health care providers to establish health goals and outcomes that are not disease-specific. The evaluation of the pilot suggested improved self-reported patient occupational performance in categories such as exercise, work, energy levels and housework, as well as improved scores for overall health, fatigue and pain. In order to truly establish the benefits of the initiative, a stronger research design with a large sample has been planned (Sampalii et al., 2012; Sampalii et al., 2016; Edwards & Sampalii, 2016).

Overall, we need to better understand the barriers that have prevented health care policy reform in the past to overcome these challenges and provide responsive care. Moreover, as the Canadian population ages, successful integrated health care pilot projects, while accounting for lessons learned from these pilot projects and past health care reform initiatives, need to be implemented at a larger scale and transferred across jurisdictions to reflect the needs of patients with multimorbidity.

### Preventative Measures: Improving social programs

As demonstrated in this study and many other previous studies, prevalence of multimorbidity is higher among those with low household income (Uijen and van de Lisdonk, 2008; Agborsangaya et al., 2012; Roberts et al., 2015). Moreover, increasing evidence from

research done around the world indicates that health outcomes – as reflected in measures from life expectancy to infant mortality and obesity – are associated with poverty within a given population (Fiscella & Franks, 1997; Gortmaker, 1979; Ogden et al., 2010). In the eyes of some, the issue is not just absolute levels of poverty and is more a matter of relative poverty or income inequality. As Marmot (2017) has pointed out, “being relatively low-income in a society where good child services are available to all, quality of schools is not dependent on the wealth of the neighbourhood, medical care is free at the point of use, public transport is available and subsidized ... will be very different from being relatively low-income in a society that lacks these...” Furthermore, a 2009 Canadian Senate report imparted that “health is more than health care and, of them all, the socio-economic environment is the most powerful of the determinants of health” (Senate Canada, 2009). This suggests that addressing socio-economic determinants will partly help address the root causes of poor health outcomes.

Although more research is needed to better understand the role of various instruments to improve equity in health, a recent study by Dutton et al. (2018) comparing how health and social spending in Canadian provinces correlates with health suggested that government spending towards social services was associated with improvements in the population-level health outcomes. The researchers also suggested that further spending on health services may not improve population-level health outcomes as effectively as spending on social services.

In Canada, *the Constitution Act*, does not directly refer to social services; however, sections 91 and 92 of the Act have been inferred to divide the authority between federal and provincial/territorial governments, with provinces/territories having primary jurisdiction (Government of Canada, 2016). As such, provision of social services varies by jurisdiction. Provincial/territorial governments offer social assistance programs such as disability support

programs, income support programs, child care benefits, etc. For example, the province of New Brunswick provides the Transitional Assistance Program to provide financial assistance to those who have a variety of intermittent foreseeable needs and the Extended Benefits Program to provide financial assistance to those have been medically certified as disabled (Government of Canada, 2016).

Similarly, various federal departments also contribute towards social assistance programs. For example, the Department of Employment and Social Development Canada (ESDC) administers or contributes to financing of some of the social assistance programs, including the Canada Learning Bond, Employment Insurance, disability support programs, Old Age Security, the Guaranteed Income Supplement, transfers to the provinces to share the cost of social assistance and postsecondary education, etc. (Government of Canada, 2017). The Department of Indigenous Services (DISC), formerly a part of Indigenous Affairs and Northern Development (INAC), follows the provincial/territorial terms and conditions to offer funding for social assistance programs to First Nation communities, who in turn deliver programs and services to community members (Government of Canada, 2016).

Although the existing social assistance programs play an import role in poverty alleviation, they are insufficient as almost 5 million or one in seven Canadians were still living in poverty in 2015 based on after-tax low-income measure (Statistics Canada, 2017b). Moreover, in 2016, the Organisation for Economic Co-operation and Development (OECD) determined that Canada's spending on social programs was 17.2% of the Gross Domestic Product (GDP), placing Canada well below the OECD average of 21% and ranking Canada in the bottom 10 of all 35 OECD countries (OECD, 2016).

However, government efforts to further contribute towards reducing inequality, particularly when framed as a health inequality issue, are often encountered with barriers such as skepticism concerning the claim that socio-economic inequality is the primary cause of health (Lynch, 2017). Another barrier is the North American commitment to the ideas that health and illness are a result of individual dispositions and actions, and therefore addressing health issues is an individual responsibility rather than a communal responsibility (Raphael et al., 2008). As a result, Lynch (2017) has recommended that “policy-makers should consider adopting more traditional programs of taxation, redistribution and labor market regulation in order to reduce both health inequalities and the underlying social inequalities.”

More traditional initiatives to address socio-economic determinants of health and to improve social services are underway across the different levels of government. For example, ESDC has been engaging with key stakeholders, including provincial, territorial and municipal governments, Indigenous people, community organizations, poverty experts and those who have experienced poverty, to develop a Canadian Poverty Reduction Strategy (Government of Canada, 2017b). During the consultation process, ESDC learned that lack of awareness of eligibility and obstacles encountered during application processes were one of the major barriers faced by low-income Canadians while accessing social programs (Government of Canada, 2017c). To address these barriers, ESDC is working towards various initiatives. For example, the Innovation Lab, a design lab which was established to find innovative solutions to service delivery challenges while promoting greater integration between policy, program and service delivery, conducted a randomized controlled trial and determined that sending a letter outlining next steps for families eligible for the Canada Learning Bond increased the take-up rate of the benefit. Similar

improvement strategies are underway for the Canada Disability Savings Program and Canada Student Loans Program (ESDC Innovation Lab, 2018).

Overall, social assistance programs delivered by federal as well as provincial and territorial governments play an important role in poverty alleviation and the governments will need to continue promoting as well as improving these programs using a social inequality frame rather than a health inequality frame to achieve tangible outcomes, including improved health outcomes.

## **CONCLUSION**

In this study, I intended to 1) provide insights into the trends in prevalence of multimorbidity from 2007-2013 in Canadian population aged 20 years and above, and 2) reproduce the findings of Roberts et al. (2015) to verify the socio-economic and health and behavioural risk factors associated with multimorbidity using a larger sample obtained by pooling together CCHS cycles from 2007-2013. The prevalence of multimorbidity defined as two or more chronic diseases increased from 11.8% to 12.6% and three or more chronic diseases increased from 3.6% to 3.9% from 2007-2013; however, the increase in prevalence was for a large part due to an aging population.

Similar to Roberts et al., multivariate regression analysis suggested that multimorbidity was significantly associated with being female, older, poor, stressed, obese, a smoker, and physically inactive. This study also suggested that multimorbidity was significantly associated with being a Canadian-born, compared to being an immigrant, and high blood pressure. Stratified logistic regression analysis revealed that being female was significantly associated with multimorbidity in those aged 20 to 64 years. Low household income was significantly associated with multimorbidity for all age groups. Household education level of less than high school

compared to completed post-secondary education was significantly associated with multimorbidity for those aged 35-64 years. Being an immigrant (compared to being Canadian born) was associated with reduced odds of having multimorbidity. Among the behavioural and health risk factors, high blood pressure, high levels of stress, being obesity and being a smoker were significantly associated with multimorbidity for all age groups.

As a response to rising number of people with multimorbidity due to an aging population, health authorities will need to keep working towards implementing integrated care approaches rather than single-diseases approaches to improve outcomes for patients with multimorbidity. Moreover, since multimorbidity is more common among disadvantaged groups, the government will need to keep improving its social assistance programs to address the root causes of ill health.

## APPENDICES

**Table A1: Prevalence of chronic conditions, by age group and sex characteristics (CCHS 2007-2013)**

	Sex	Prevalence (%) (95% CI)	Prevalence of each condition, (%), by age group (years) (95% CI)			
			20-34	35-49	50-64	≥ 65
<b>Arthritis</b>	Female	20.9 (20.7-21.2)	3.1 (2.9-3.4)	10.3 (9.8-10.8)	28.5 (27.8-29.1)	49.6 (49.0-50.2)
	Male	13.5 (13.2-13.7)	2.2 (1.9-2.4)	7.5 (7.1-8.0)	19.1 (18.5-19.7)	33.2 (32.5-33.8)
<b>Mental Disorders</b>	Female	13.4 (13.1-13.6)	13.1 (12.6-13.5)	14.1 (13.6-14.7)	15.1 (14.6-15.6)	10.3 (10.0-10.6)
	Male	7.9 (7.7-8.1)	7.5 (7.1-7.9)	8.3 (7.8-8.7)	8.9 (8.4-9.3)	6.4 (6.1-6.8)
<b>Asthma</b>	Female	9.2 (9.0-9.4)	10.2 (9.8-10.7)	8.8 (8.4-9.3)	9.1 (8.7-9.5)	8.4 (8.1-8.8)
	Male	6.5 (6.3-6.7)	8.0 (7.6-8.4)	6.1 (5.8-6.5)	5.4 (5.1-5.7)	6.3 (6.0-6.7)
<b>Diabetes Mellitus</b>	Female	6.3 (6.1-6.4)	1.0 (0.9-1.1)	3.0 (2.7-3.2)	8.4 (8.0-8.8)	15.0 (14.6-15.5)
	Male	7.8 (7.6-8.0)	0.9 (0.7-1.0)	3.7 (3.4-4.0)	11.2 (10.7-11.7)	20.4 (19.9-21.0)
<b>Heart Disease</b>	Female	4.6 (4.4-4.7)	0.6 (0.5-0.7)	1.5 (1.2-1.7)	4.3 (4.0-4.6)	14.7 (14.3-15.2)
	Male	6.2 (6.1-6.4)	0.6 (0.5-0.7)	1.6 (1.4-1.8)	7.8 (7.4-8.3)	21.0 (20.4-21.5)
<b>COPD</b>	Female	4.8 (4.6-5.0)		2.4 (2.2-2.6)	5.0 (4.7-5.2)	8.0 (7.7-8.3)
	Male	4.0 (3.9-4.2)		1.8 (1.6-2.0)	3.9 (3.6-4.1)	8.2 (7.8-8.5)
<b>Cancer</b>	Female	2.3 (2.2-2.4)	0.3 (0.2-0.4)	1.1 (0.9-1.3)	3.0 (2.8-3.2)	5.6 (5.3-5.8)
	Male	2.1 (2.0-2.2)	0.1 (0.1-0.2)	0.5 (0.4-0.6)	2.5 (2.3-2.7)	7.2 (6.9-7.6)
<b>Side-effects of stroke</b>	Female	1.2 (1.1-1.3)	0.1 (0.1-0.2)	0.4 (0.3-0.5)	1.2 (1.0-1.4)	3.7 (3.5-4.0)
	Male	1.3 (1.2-1.3)	0.1 (0.1-0.2)	0.4 (0.3-0.5)	1.3 (1.1-1.4)	4.6 (4.3-4.9)

**Abbreviations:** CCHS, Canadian Community Health Survey COPD, chronic obstructive pulmonary disease; CI, confidence interval

**Note 1:** Mental disorders are mood disorders and/or anxiety.

**Note 2:** Data on COPD was only available for ages 35 years and older.

**Table A2: Prevalence of the most common chronic disease dyads in those with multimorbidity, overall and by age group, (CCHS 2007-2013, population aged ≥ 20 years)**

Disease Dyads (Prevalence,%; 95% CI)				
Overall	Age 20-34 years	Age 35-49 years	Age 50-64 years	Age ≥ 65 years
Mental Disorder and Arthritis (25.0; 25.0-25.0)	Mental Disorder and Asthma (57.3; 54.5-60.1)	Mental Disorder and Arthritis (35.3; 33.4-37.3)	Mental Disorder and Arthritis (31.4; 30.3-32.5)	Arthritis and Heart Disease (29.2; 28.5-29.9)
Arthritis and Diabetes (20.3; 20.3-20.3)	Mental Disorder and Arthritis (23.6; 21.2-25.9)	Mental Disorder and Asthma (24.7; 23.0-26.4)	Arthritis and Diabetes (20.3; 19.3-21.2)	Arthritis and Diabetes (26.9; 26.2-27.6)
Arthritis and Heart Disease (18.3; 18.3-18.3)	Arthritis and Asthma (17.1; 15.2-19.1)	Arthritis and Asthma (21.2; 19.5-22.8)	Arthritis and Asthma (19.2; 18.3-20.1)	Mental Disorder and Arthritis (16.6; 16.0-17.1)
Arthritis and Asthma (17.1; 17.1-17.1)		Asthma and COPD (11.8; 10.5-13.0)	Arthritis and Heart Disease (13.3; 12.4-14.1)	Diabetes and Heart Disease (14.9; 14.3-15.5)
Mental Disorder and Asthma (12.8; 12.8-12.8)		Mental Disorder and COPD (10.4; 9.2-11.7)	Arthritis and COPD (13.2; 12.3-14.1)	Arthritis and COPD (14.8; 14.2-15.3)
Arthritis and COPD (12.6; 12.6-12.6)		Mental Disorder and Diabetes (10.1; 8.8-11.4)	Mental Disorder and Asthma (11.1; 10.3-11.9)	Arthritis and Asthma (14.0; 13.5-14.5)
Diabetes and Heart Disease (10.4; 10.4-10.4)				

**Abbreviations:** CCHS, Canadian Community Health Survey; CI, confidence interval; COPD, chronic obstructive pulmonary disease.

Prevalence measures represent dyad estimates in those with 2+ chronic disease multimorbidity. Only disease combinations with a prevalence of >10% within each age group are included in the table.

**Note 1:** Mental disorders are mood disorders and/or anxiety.

**Note 2:** Data on COPD was only available for ages 35 years and older.

**Table A3: Prevalence of the most common chronic disease triads in those with multimorbidity, overall and by age group, (CCHS 2007-2013, population aged ≥ 20 years)**

Disease Triads (Prevalence,%; 95% CI)				
Overall	Age 20-34 years	Age 35-49 years	Age 50-64 years	Age ≥ 65 years
Arthritis, Mental Disorder & Asthma (16.1; 16.1-16.1)	Arthritis, Asthma & Mental Disorder (57.5; 49.5-65.4)	Arthritis, Asthma & Mental Disorder (35.1; 31.5-38.7)	Arthritis, Asthma & Mental Disorder (20.4; 18.7-22.1)	Arthritis, Diabetes & Heart Disease (21.7; 20.6-22.8)
Arthritis, Diabetes & Heart Disease (16.1; 16.1-16.1)	Asthma, Heart Disease & Mental Disorder (11.7; 7.4-16.0)	Asthma, COPD & Mental Disorder (20.0; 17.0-23.0)	Arthritis, Asthma & COPD (18.4; 16.8-19.9)	Arthritis, COPD & Heart Disease (13.2; 12.3-14.0)
Arthritis, COPD & Asthma (15.2; 15.2-15.2)		Arthritis, COPD & Mental Disorder (17.9; 14.9-20.8)	Arthritis, COPD & Mental Disorder (16.3; 14.8-17.8)	Arthritis, Asthma & COPD (13.1; 12.2-13.9)
Arthritis, Mental Disorder & COPD (12.1; 12.1-12.1)		Arthritis, Asthma & COPD (16.5; 13.8-19.1)	Arthritis, Diabetes & Mental Disorder (15.5; 14.1-16.9)	Arthritis, Heart Disease & Mental Disorder (11.7; 11.0-12.5)
Arthritis, Mental Disorder & Diabetes (12.0; 12.0-12.0)		Arthritis, Diabetes & Mental Disorder (13.8; 11.2-16.3)	Arthritis, Diabetes & Heart Disease (12.5; 11.3-13.7)	Arthritis, Asthma & Heart Disease (10.3; 9.5-11.0)
Arthritis, Mental Disorder & Heart Disease (11.7; 11.7-11.7)		Arthritis, Mental Disorder & Heart Disease (10.0; 7.9-12.2)	Asthma, COPD & Mental Disorder (12.3; 10.9-13.7)	
Arthritis, Asthma & Diabetes (10.1; 10.1-10.1)			Arthritis, Mental Disorder & Heart Disease (12.3; 10.5-14.1)	
			Arthritis, Asthma & Diabetes (11.1; 9.9-12.2)	

**Abbreviations:** CCHS, Canadian Community Health Survey; CI, confidence interval; COPD, chronic obstructive pulmonary disease.

Prevalence measures represent triad estimates in those with 3+ chronic disease multimorbidity. Only disease combinations with a prevalence of >10% within each age group are included in the table.

**Note 1:** Mental disorders are mood disorders and/or anxiety.

**Note 2:** Data on COPD was only available for ages 35 years and older.

**Table A4: Analysis of association between socio-demographic and health and behavioural risk factors and multimorbidity<sup>a</sup> (CCHS 2007-2013, population aged ≥ 20 years)**

	Adjusted OR (95% CI) <sup>b</sup>	
	2+ Chronic Diseases	3+ Chronic Diseases
<b>Year</b>		
2007 (referent)	1.00	1.0
2009	1.0 (0.9-1.0)	1.0 (0.9-1.1)
2011	1.1 (1.0-1.1) *	1.0 (0.9-1.1)
2013	1.1 (1.0-1.1)	1.1 (1.0-1.2)
<b>Sex</b>		
Female	1.4 (1.3-1.4) ***	1.2 (1.1-1.3) ***
Male (referent)	1.0	1.0
<b>Age, years</b>		
20-34 (referent)	1.0	1.0
35-49	2.0 (1.9-2.2) ***	3.9 (3.2-4.7) ***
50-64	4.7 (4.3-5.0) ***	10.0 (8.2-12.1) ***
≥ 65	8.8 (8.1-9.5) ***	18.3 (15.0-22.4) ***
<b>Household Income</b>		
<\$20,000	3.1 (2.9-3.4) ***	4.4 (3.9-4.9) ***
\$20,000-\$39,999	2.0 (1.9-2.1) ***	2.5 (2.2-2.8) ***
\$40,000-\$59,999	1.5 (1.4-1.6) ***	1.8 (1.6-2.0) ***
\$60,000-\$79,000	1.3 (1.2-1.3) ***	1.4 (1.2-1.6) ***
\$80,000 and over (referent)	1.0	1.0
<b>Household Education</b>		
Less than high school	1.0 (1.0-1.1)	1.1 (1.0-1.2) *
High school completed	1.0 (0.9-1.1)	1.0 (0.9-1.1)
Some post-secondary	1.1 (1.0-1.2) **	1.2 (1.1-1.4) **
Post-secondary completed (referent)	1.0	1.0
<b>Immigration Status</b>		
Lived in Canada <10 years	0.3 (0.2-0.4) ***	0.3 (0.2-0.4) ***
Lived in Canada ≥ 10 years	0.8 (0.7-0.8) ***	0.7 (0.6-0.7) ***
Canadian-born (referent)	1.0	1.0
<b>Risk Factors</b>		
High blood pressure	2.1 (2.0-2.2) ***	2.5 (2.4-2.7) ***
High Stress	2.0 (1.9-2.1) ***	2.2 (2.1-2.4) ***
Obese	2.0 (1.9-2.1) ***	2.1 (2.0-2.3) ***
Smoker	1.5 (1.4-1.5) ***	1.6 (1.5-1.7) ***
Inactive	1.3 (1.2-1.3) ***	1.5 (1.4-1.6) ***
< 5 servings of fruit and vegetables/day	1.1 (1.0-1.1) *	1.0 (0.9-1.1)

**Abbreviations:** CCHS, Canadian Community Health Survey; CI, confidence interval

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 2 or more or 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

**Table A5: Analysis of association between socio-demographic and health and behavioural risk factors and multimorbidity<sup>a</sup> with the ≥ 65 age group segmented (CCHS 2007-2013, population aged ≥ 20 years)**

	Adjusted OR (95% CI) <sup>b</sup>	
	2+ Chronic Diseases	3+ Chronic Diseases
<b>Year</b>		
2007 (referent)	1.00	1.0
2009	1.0 (0.9-1.0)	1.0 (0.9-1.1)
2011	1.1 (1.0-1.1) *	1.0 (0.9-1.1)
2013	1.1 (1.0-1.1)	1.1 (1.0-1.2)
<b>Sex</b>		
Female	1.3 (1.3-1.4) ***	1.2 (1.1-1.3) ***
Male (referent)	1.0	1.0
<b>Age, years</b>		
20-34 (referent)	1.0	1.0
35-49	2.0 (1.9-2.2) ***	3.9 (3.2-4.7) ***
50-64	4.7 (4.4-5.1) ***	10.1 (8.3-12.2) ***
65-69	7.1 (6.5-7.7) ***	15.4 (12.5-18.9) ***
70-74	9.0 (8.3-9.9) ***	18.5 (15.0-22.8) ***
75-89	10.6 (9.6-11.6) ***	21.3 (17.2-26.4) ***
≥ 80	11.5 (10.5-12.7) ***	23.8 (19.2-29.4) ***
<b>Household Income</b>		
<\$20,000	3.1 (2.9-3.3) ***	4.3 (3.9-4.9) ***
\$20,000-\$39,999	2.0 (1.9-2.1) ***	2.4 (2.2-2.7) ***
\$40,000-\$59,999	1.5 (1.4-1.6) ***	1.8 (1.6-2.0) ***
\$60,000-\$79,000	1.3 (1.2-1.3) ***	1.4 (1.2-1.6) ***
\$80,000 and over (referent)	1.0	1.0
<b>Household Education</b>		
Less than high school	1.0 (1.0-1.1)	1.0 (1.0-1.1)
High school completed	1.0 (0.9-1.0)	1.0 (0.9-1.1)
Some post-secondary	1.1 (1.0-1.2) **	1.2 (1.1-1.4) **
Post-secondary completed (referent)	1.0	1.0
<b>Immigration Status</b>		
Lived in Canada <10 years	0.3 (0.2-0.4) ***	0.3 (0.2-0.5) ***
Lived in Canada ≥ 10 years	0.8 (0.7-0.8) ***	0.7 (0.6-0.7) ***
Canadian-born (referent)	1.0	1.0
<b>Risk Factors</b>		
High blood pressure	2.1 (2.0-2.2) ***	2.5 (2.3-2.6) ***
High Stress	2.0 (1.9-2.1) ***	2.3 (2.1-2.4) ***
Obese	2.0 (1.9-2.1) ***	2.2 (2.1-2.3) ***
Smoker	1.5 (1.4-1.5) ***	1.7 (1.6-1.8) ***
Inactive	1.2 (1.2-1.3) ***	1.4 (1.3-1.5) ***
< 5 servings of fruit and vegetables/day	1.1 (1.0-1.1) **	1.0 (1.0-1.1)

**Abbreviations:** CCHS, Canadian Community Health Survey; CI, confidence interval

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 2 or more or 3 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

**Table A6: Analysis of the association between gender and multimorbidity<sup>a</sup> (2+ chronic diseases) by age (CCHS 2007-2013)**

Sex	Adjusted OR (95% CI) <sup>b</sup> by age, years			
	20 -34	35-49	50-64	≥ 65
Female	2.2 *** (1.9-2.6)	1.9 *** (1.8-2.2)	1.5 *** (1.4-1.6)	1.0 (0.9-1.0)
Male (referent)	1.0	1.0	1.0	1.0

**Abbreviations:** CCHS, Canadian Community Health Survey; OR, odds ratio; CI, confidence interval

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 2 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

**Table A7: Analysis of the association between household income and multimorbidity<sup>a</sup> (2+ chronic diseases) by age (CCHS 2007-2013)**

Household Income	Adjusted OR (95% CI) <sup>b</sup> by age, years			
	20 -34	35-49	50-64	≥ 65
<\$20,000	3.6 *** (2.9-4.5)	4.8 *** (4.1-5.7)	3.8 *** (3.4-4.2)	1.8 *** (1.6-2.0)
\$20,000-\$39,999	2.0 *** (1.6-2.4)	2.5 *** (2.2-2.9)	2.0 *** (1.8-2.2)	1.5 *** (1.3-1.6)
\$40,000-\$59,999	1.9 *** (1.5-2.4)	1.7 *** (1.4-1.9)	1.4 *** (1.3-1.5)	1.2 *** (1.1-1.3)
\$60,000-\$79,000	1.3 * (1.0-1.6)	1.3 *** (1.1-1.6)	1.2 *** (1.1-1.3)	1.1 (1.0-1.2)
\$80,000 and over (referent)	1.0	1.0	1.0	1.0

**Abbreviations:** CCHS, Canadian Community Health Survey; OR, odds ratio; CI, confidence interval

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 2 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

**Table A8: Analysis of the association between highest household education level and multimorbidity<sup>a</sup> (2+ chronic diseases) by age (CCHS 2007-2013)**

Highest Household Education	Adjusted OR (95% CI) <sup>b</sup> by age, years			
	20 -34	35-49	50-64	≥ 65
Less than high school	1.3 * (1.0-1.6)	1.1 (0.9-1.3)	1.2 *** (1.1-1.4)	1.0 (1.0-1.1)
High school completed	1.0 (0.8-1.2)	1.1 (0.9-1.3)	1.0 (0.9-1.1)	0.9 (0.9-1.0)
Some post-secondary	1.0 (0.8-1.3)	1.3 * (1.0-1.6)	1.1 (0.9-1.2)	1.2 * (1.0-1.3)
Post-secondary completed (referent)	1.0	1.0	1.0	1.0

**Abbreviations:** CCHS, Canadian Community Health Survey; OR, odds ratio; CI, confidence interval

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 2 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

**Table A9: Analysis of the association between immigration status and multimorbidity<sup>a</sup> (2+ chronic diseases) by age (CCHS 2007-2013)**

Immigration Status	Adjusted OR (95% CI) <sup>b</sup> by age, years			
	20 -34	35-49	50-64	≥ 65
Lived in Canada <10 years	0.2 *** (0.1-0.5)	0.3 *** (0.2-0.4)	0.4 *** (0.2-0.6)	0.4 * (0.2-0.8)
Lived in Canada ≥ 10 years	0.4 ** (0.2-0.7)	0.5 *** (0.5-0.7)	0.8 *** (0.7-0.9)	0.8 *** (0.8-0.9)
Canadian-born (referent)	1.0	1.0	1.0	1.0

**Abbreviations:** CCHS, Canadian Community Health Survey; OR, odds ratio; CI, confidence interval

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 2 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

**Table A10: Analysis of the association between health and behavioural risk factors and multimorbidity<sup>a</sup> (2+ chronic diseases) by age (CCHS 2007-2013)**

Risk Factors	Adjusted OR (95% CI) <sup>b</sup> by age, years			
	20 -34	35-49	50-64	≥ 65
High blood pressure	4.0 *** (3.1-5.3)	2.8 *** (2.5-3.2)	2.2 *** (2.0-2.3)	1.7 *** (1.7-1.8)
High stress	2.2 *** (1.9-2.6)	2.1 *** (1.9-2.3)	1.8 *** (1.7-1.9)	2.0 *** (1.9-2.2)
Obese	2.0 *** (1.7-2.3)	2.0 *** (1.8-2.3)	2.1 *** (1.9-2.2)	1.7 *** (1.6-1.8)
Smoker	1.8 *** (1.5-2.1)	1.7 *** (1.6-1.9)	1.3 *** (1.2-1.4)	1.1 (1.0-1.1)
Inactive	1.0 (0.9-1.1)	1.1 (0.9-1.2)	1.3 *** (1.2-1.4)	1.5 *** (1.5-1.6)
< 5 servings of fruit and vegetables/day	1.1 (0.9-1.2)	1.1 (0.9-1.2)	1.0 (1.0-1.1)	1.1 * (1.0-1.1)

**Abbreviations:** CCHS, Canadian Community Health Survey; OR, odds ratio; CI, confidence interval

\* indicates statistical significance at  $p < 0.05$ , \*\* at  $p < 0.01$  and \*\*\* at  $p < 0.001$ .

<sup>a</sup> Multimorbidity defined as 2 or more of the following 8 diseases: asthma, arthritis, chronic obstructive pulmonary disease, diabetes, heart disease, mental disorder (mood disorder and/or anxiety), cancer, and side-effects of stroke.

<sup>b</sup> Odds ratio adjusted for year, sex, age, household income, highest household education level, immigration status, high blood pressure, obesity, activity level, high stress, consumption of fruits and vegetables and smoking status.

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