Do we need a new perspective on chronic diseases? The combined effects of workplace stress and socioeconomic status as non-traditional disease risk factors in Canada

by

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Author's Declaration

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

Abstract

Background: Approximately 80% of Canadians over the age of 20 are at risk of developing a chronic disease (CD) such as cardiovascular disease (CVD) and type II diabetes (T2D) (Artham, Lavie, Milani, & Ventura, 2009; PHAC, 2017; Yach, 2004). The burden of CD is not distributed equally amongst Canadians either, with those from lower socioeconomic status (SES) backgrounds having higher CD outcomes and poorer health overall (Patra, 2007). Although the role of stress has often been implicated in the development of CVD and T2D, research on the combined effects of stress and SES is lacking in Canada (Cotter & Kelly, 2018; Crompton, 2011; Ferris, Kline, & Bourdage, 2012; Guan, Collet, Mazowita, & Claydon, 2018; Hughes, Lu, & Howard, 2018; Smith, Frank, & Mustard, 2008; Steptoe, Siegrist, Kirschbaum, & Marmot, 2004). The highest source of stress amongst Canadian adults is reported to be due to work instead of finances; therefore, workplace stress and SES might have cumulative effects that can increase the odds of developing CVD and T2D (Kivimaki & Kawachi, 2015).

Objective: This study investigated if self-reported stress levels and measures of socioeconomic status (including household income, household education level, and occupational type) were significantly associated to self-reported diagnosis of CVD and T2D, even after controlling for traditional risk factors: smoking status, alcohol intake, fruit and vegetable intake, and physical activity (Pouwer, Kupper, & Adriaanse, 2010). Further analysis sought to investigate the combined effects of both SES and workplace stress on CD outcomes by calculating the magnitude of their multiplicative interaction and additive interaction via reporting the relative excess risk due to interaction (RERI).

Methods: A cross-sectional analysis was conducted through multivariate logistic regression analysis using a bootstrapped weighted sample of 78,023 respondents from the Canadian Community Health Survey (2015-16). Models initially controlled for age, sex, race or cultural background, and body mass index (BMI), and subsequently the traditional risk factors to understand the true association between stress and SES on CD outcomes. Combined effects of both main variables were assessed using multiplicative and additive interaction analysis.

Results: Outcomes from logistic regression analyses showed a significant association between perceived life stress and all aspects of SES for both CVD and T2D. Perceived life stress and SES remained significantly associated to both CD outcomes even after adjusting for traditional behaviour risk factors. A significant interaction between high life stress and low household income showed almost double the odds of reporting diabetes (OR=1.89, p=0.03), compared to the product of the individual factors alone. Results support that perceived stress and SES might have independent associations to CD outcome and together they might have cumulative effects on health.

Conclusion: Our results corroborate other findings that stress and SES might have independent associations to CD outcomes, even in the absence of traditional disease risk factors. These results highlight the importance of understanding the cumulative effects social and economic factors in exacerbating CD outcomes. To our knowledge, this is the first Canadian study to show the cumulative effects of perceived stress and SES on outcomes of CVD and diabetes, and why we might need to change our approach to combat incidence of CDs.

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To those unlucky enough to read this thesis in your spare time, whether you're looking for guidance on your own research or trying to understand some of the concepts in this study, my advice is to just keep going. Every day you come across new information that helps you become a better researcher, and you continue to take small steps down the path of becoming a critical thinker. The only catch is, you can't see how far you've come when you take small steps, so, just keep going.

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List of Abbreviations

ANS	Autonomic Nervous System
AP	Attributable Portion
BMI	Body Mass Index
CCHS	Canadian Community Health Survey
CD	Chronic Disease
CHD	Coronary Heart Disease
CVD	Cardiovascular Disease
EDA	Exploratory Data Analysis
ERI	Effort-Reward-Imbalance
FMD	Flow-Mediated Dilation
HPA	Hypothalamic-pituitary-adrenal
HRV	Heart rate variability
JDC	Job-Demand-Control
LDL	Low-density lipoprotein
NCD	Non-communicable Disease
OR	Odds Ratio
PHAC	Public Health Agency of Canada
RERI	Relative Excess Risk due to Interaction
RR	Relative Risk
S	Synergy Index
SEP	Socioeconomic Position
SES	Socioeconomic Status
SSS	Subjective Social Status
T2D	Type II Diabetes
UBI	Universal Basic Income
VTE	Venous Thromboembolism

Chapter 1.0. Introduction and Study Rationale

As the largest cause of death in both developing and developed countries, chronic diseases are now the greatest public health challenge of our time (Meetoo, 2008; Yach, 2004). The leading causes of death worldwide are cardiovascular disease, followed by cancer, chronic respiratory disease, and diabetes mellitus (Meetoo, 2008; Mendis, Davis, & Norrving, 2015; Yach, Hawkes, Gould, & Hofman, 2004). These diseases are also termed "noncommunicable" because they are not transferrable to another person, develop slowly over time, and adversely affect physical, psychological, and social functioning (Megari, 2013; MOHLTC, 2018). As in the rest of the world, the majority of deaths in Canada are also due to chronic diseases, and more than half of the adult population suffers from one (Advisory Committee for Chronic Disease, 2005; Betancourt et al., 2014; PHAC, 2013). This burden is projected to further increase due to the aging population, as older adults are known to suffer from higher rates of CDs (Betancourt, 2014; MOHLTC, 2018; Sanmartin, 2015).

Along with dire health consequences for individuals, chronic diseases also place a great economic burden on Canada's health care system (Chronic Disease Prevention Alliance of Canada, 2017). Direct costs of disease and indirect costs related to losses in productivity and income account for almost 60% of annual health care costs in Canada (Chronic Disease Prevention Alliance of Canada, 2017; Patra, 2007). The direct costs of CDs are estimated to be nearly $68 billion, with indirect costs making up the larger sum at $122 billion. This results in a grand total of $190 billion spent annually on chronic diseases (Chronic Disease Prevention Alliance of Canada, 2017). Due to the foreseeable increase in older adults and multimorbidity—the co-existence of two or more chronic diseases—financial costs associated with CDs may impact the future sustainability of Canada's healthcare system (Feely, Lix, & Reimer, 2017; Pefoyo et al., 2015; PHAC, 2013; Sanmartin, 2015).

Nevertheless, CDs are considered to be largely preventable and caused by modifiable risk factors; namely, physical inactivity, unhealthy diet, smoking, and alcohol intake (Centers for Disease Control and Prevention, 2009; MOHLTC, 2018; PHAC, 2013; WHO, 2005b, 2009). Although it has been assumed that the increased prevalence of CDs is due to the population living longer, the World Health Organization (WHO) estimated that nearly 80% of cardiovascular diseases (CVD) and type II diabetes (T2D) can be prevented; therefore, older adults are not destined for noncommunicable disease (NCD) (Centers for Disease Control and Prevention, 2009; WHO, 2005b). Currently, four out of five Canadians over the age of 20 already have one modifiable risk factor that increases their probability of developing a CD (Betancourt, 2014). To tackle this issue, in 2005, the federal government made a $300 million investment to address modifiable risk factors (Patra, 2007; PHAC, 2005). However, despite these efforts, combating CDs has proven itself a more difficult task than anticipated as there are numerous social and economic factors that can also exacerbate disease outcomes (Beaglehole et al., 2011; Canadian Institute for Health Information, 2006).

It is well-known that chronic diseases are more prevalent amongst individuals living under low socioeconomic status (SES) conditions, which includes three aspects: income, educational attainment, and occupational prestige (Canadian Institute for Health Information, 2015; Lasser, Himmelstein, & Woolhandler, 2006; Roos, 1997; Statistics Canada, 2009). On the other hand, successful public health campaigns have disproportionately benefited those from higher socioeconomic backgrounds. For example, interventions aimed at reducing tobacco inhalation have succeeded in combating the incidence of heart and respiratory diseases, but a higher prevalence of smoking continues to exist among low socioeconomic groups (Canadian Institute for Health Information, 2006; McIvor, 2009; Reid, 2010). Lower SES groups are also less likely to access medical services, which are an integral part of receiving better preventive care (Talbot, 2001). This is how low socioeconomic conditions can influence factors such as adoption of healthy lifestyle behaviours and access to healthcare (Canadian Institute for Health Information, 2006, 2015; Roos, 1997; Talbot, 2001). Thus, CDs may continue to have a higher prevalence amongst those from a low socioeconomic position in Canada due to social disparities.

Although Canada has reached its lowest poverty rate in history, recent decades continue to show increased polarization between low and high income groups (Institute for Research on Public Policy, 2017; OECD, 2008, 2011, 2015; Statistics Canada, 2014). Beginning in the 1980s, research shows that income inequality has increased in Canada (Baker & Solon, 2003; Fortin, Green, Lemieux, Milligan, & Riddell, 2012). A growing income gap is still concerning because our perception of social position, or subjective socioeconomic status, can also have negative health outcomes (Cooper et al., 2010). Researchers have termed this as our perception of "deprivation", a state of demonstrable disadvantage relative to the local community or wider society or nation to which an individual, family, or group belongs (Matheson, Dunn, Smith, Moineddin, & Glazier, 2012; Pampalon, Hamel, Gamache, & Raymond, 2009). This extends beyond material deprivation to incorporate economic inequality, residential instability, ethnic concentration, and dependency. Research in Canada indicates that a higher degree of deprivation is significantly associated to chronic diseases and health behaviour problems such as binge drinking (Matheson et al., 2012). The changing economic circumstances may thus create greater feelings of deprivation due to increasing income inequality.

The importance of the economic environment has been described by a public health framework known as the "health impact pyramid", which specifies the level of impact an intervention can likely achieve within the population level it is targeting. The pyramid places socioeconomic factors at the base, emphasizing that economic factors have the greatest impact on changing the health of a population (Frieden, 2010). As mentioned, interventions in Canada had primarily focused on traditional risk factors including smoking tobacco, unhealthy diets, physical inactivity, and excessive alcohol consumption (MOHLTC, 2018; PHAC, 2005, 2013). However, due to a lack of results in CD prevention, we now realize the shortcomings of such awareness-based approaches (Frieden, 2010; PHAC, 2015). The Public Health Agency of Canada (PHAC) is now seeking new solutions to the complex challenges presented by chronic disease (PHAC, 2015). This recent change will be carried out by accepting new perspectives and approaches on behavioural economics and social innovation, and using big data to implement policy and program changes (PHAC, 2015). Government agencies are thus recognizing the complexity of CDs and their interconnectedness to broader factors such as economic changes that are out of an individual's control.

The social environment can also greatly impact an individual by leading to physiological changes in the brain and body to aid fight or flight responses. Over time, stressful social situations have proven to cause maladaptive bodily changes that result in a higher risk of developing CDs (McEwen, 2012). For example, social pressures or stressful circumstances can lead to higher chronic stress levels that have been associated with higher outcomes of CVD and T2D (Dimsdale, 2008; Harris et al., 2017; Salleh, 2008; Tawakol et al., 2017). This is suggestive of cumulative wear and tear over a lifetime where once a threshold is reached, the body becomes predisposed to chronic illness (McEwen, 2012). Positive social environments should foster stable social connections, social participation, social capital, and effective neighbourhood and work environments (Ahern, 2011; National Research Council & Committee on Population, 2013). Research has shown that immediate social environments such as school, work, or neighbourhoods can influence both physical and mental health outcomes (De Silva, 2005; National Research Council & Committee on Population, 2013). Therefore, chronically stressful social environments can be a non-traditional risk factor for CD outcomes.

Work, rather than finances, is reported to be the highest source of stress amongst Canadians (Crompton, 2011). Researchers are now trying to understand how the workplace environment may be a non-traditional risk factor for exacerbating CDs. Studies in Canada are beginning to investigate how certain aspects of the psychosocial work environment including low job control, number of hours worked per week, and physical exertion at work may exacerbate outcomes of CVD and T2D (Nowrouzi-Kia, 2018; Smith, 2012). One of the occupational risk factors Nowrouzia-Kia et al. found is an aspect of SES—occupation type (2018). Even though there may be an overlap between stressful work environments and socioeconomic conditions, it is not well known how these two non-traditional risk factors work in tandem to influence CD outcomes in Canada. Previous studies have either focused solely on economic conditions or the psychosocial aspects of the workplace, but the combined effects these risk factors remains little understood (Bird, Lemstra, Rogers, & Moraros, 2015; Smith, 2012). Thus, to improve prevention efforts against combating the complexity of CDs, we need to investigate the effects of both social and economic risk factors simultaneously.

So far, our understanding of non-traditional risk factors is lacking behind research focusing on behaviours such as smoking, physical activity, and diet, and their relationship to CD outcomes. The PHAC has recognized the need for innovation in addressing CDs and is seeking new solutions to these complex issues (PHAC, 2015). However, studying one non-traditional risk factor at a time compromises the real-world complexity of the issue, which is why we need to understand the combined effects of social and economic risk factors such as workplace stress and SES on outcomes of CDs, respectively. Because the WHO has estimated that a majority of CVD and T2D cases can be prevented (2005), this research will seek to investigate the joint effects of SES and workplace stress on outcomes of these two CDs. Further information on the real-world complexity of chronic diseases can hopefully shed light on impactful population-level interventions in the future.

Chapter 2.0. Literature Review

This literature review will discuss what has been previously studied in order to identify existing gaps in knowledge within the Canadian context. In an effort to situate the research objective, this chapter will review existing scholarly literature regarding mental and social stress, SES, and chronic cardiometabolic diseases—specifically CVD and T2D. Due to a lack of Canadian research in this area, we will first focus on information conducted globally. To begin, we examine the association between chronic or workplace stress and cardiovascular diseases, followed by the effect of socioeconomic status on heart disease outcomes. Subsequently, we will review metabolic health to understand the effect of workplace stress and socioeconomic status on type II diabetes.

Cardiovascular Disease

2.1. Effect of Chronic Stress, Workplace Stress, or Job Strain on Cardiovascular Health

Cardiovascular abnormalities are all related to the dysfunction of the heart and blood vessels, and thus a wide range of disorders will be discussed in this review. We define "stress" as exceeding demands that outweigh the psychosocial resources or adaptive capacity of an individual (Steptoe & Kivimäki, 2012). The chronicity of the stressor can further negatively impact physiological responses and overtime lead to maladaptive changes in the body. Numerous types of stress have been implicated in the development of CVD, including: oxidative stress, hemodynamic stress, mental stress, and social stress (Inoue, 2014). Social and mental stress in particular contribute to the development and progression of CVD through atherosclerosis or by triggering acute CVD events such as myocardial infarction (i.e. heart attack) (Chinnaiyan, 2019; Inoue, 2014). Researchers have found that regardless of gender or ethnicity within a sample of 11,119 patients and 13,648 controls, patients with a history of myocardial infarction had a higher prevalence of mental and social stress than controls (Yusuf et al., 2004). Since the highest source of stress for

Canadians is work, workplace stress or job strain will be discussed in greater detail as one source of mental and social stress (Crompton, 2011). Later in this chapter, we will discuss the importance of the sympathetic nervous system and the hypothalamic-pituitary-adrenal (HPA) axis in producing physiological changes in response to chronic stress.

Numerous studies have concluded that higher workplace stress—used interchangeably with job strain in this review—results in a higher development of cardiovascular abnormalities including atherosclerotic disease, hypertension, ischemic stroke, coronary artery disease, coronary heart disease (CHD), myocardial infarction, coronary revascularization, and cardiovascular disease (CVD) (i.e. heart disease) (Conway, Pompeii, Roberts, Follis, & Gimeno, 2016; Fujishiro et al., 2011; Guan et al., 2017; Rocco et al., 2017; Slopen et al., 2012; Sultan-Taieb, Chastang, Mansouri, & Niedhammer, 2013; Trudel, Brisson, & Milot, 2010; Tsai, 2012). Workplace stress can result from multiple factors including, but not limited to, long working hours, having low control on the job, high demand at work, job insecurity, shift work, and repetitive assembly line work (Clougherty, Eisen, Slade, Kawachi, & Cullen, 2009; Landsbergis et al., 2013). Categorization of these stressors has led to the development of theoretical models that aid our understanding of which specific aspects of a workplace can induce a stress response. The effort-reward-imbalance model (ERI), the job-demand-control (JDC) model, and the organizational injustice model, all shed light on different types of stressful work environments, and all three are discussed in greater detail below (Francis & Barling, 2005; Häusser, Mojzisch, Niesel, & Schulz-Hardt, 2010; Siegrist, Wege, Pühlhofer, & Wahrendorf, 2009). Moreover, only longitudinal studies can identify the temporality of the association between workplace stress and CVD—that the exposure to stress preceded the development of heart disease. Thus, we will discuss research from longitudinal studies that are able to show the time of development (i.e. incidence) of CVD.

Several longitudinal studies have been able to distinguish the chronological order of workplace stress and CVD outcome, thereby helping us understand the direction of the association.

Landsbergis et. al. (2013) examined the association between long work hours and assembly-line work and cardiovascular disease outcomes in the United States over a 6-year period. Surveying a total of 64,533 employees across 51 facilities, the authors found that overtime working hours and assembly-line work were associated with a higher risk of developing CVD. In addition, a meta-analysis comparing 17 longitudinal studies showed a positive association between job strain and CVD risk (Belkic, Landsbergis, Schnall, & Baker, 2004). These researchers found the strongest association in men, with less consistent results for women (Belkic et al., 2004). This strong association specifically in men was also found in a multicohort study conducted between 1985 to 2002 in Finland, France, Sweden, and the UK, which showed high job strain had significantly contributed to increased mortality in men with cardiometabolic diseases (including CVD and T2D) (Kivimaki et al., 2018). Thus, there seems to be evidence from outside of Canada across multiple longitudinal studies that show a positive association between workplace stress or job strain and a later onset of CVD. Research is scarce in Canada due to a lack of longitudinal population level health data. However, in determining the relationship between workplace stress and CVD, it may be safe to assume that a chronic stressful exposure preceded the development of heart disease. Therefore, it will be useful to analyze cross-sectional Canadian data to gain a better understanding of the present situation.

Although longitudinal research within Canada on workplace stress and CVD is scarce, it is important to highlight the most recent longitudinal study. Researchers used data from workers aged 40 years and older and found that occupational stressors measured in the National Population Health Survey (NPHS) were not associated with the development of heart disease, other than amongst women exposed to physical demands at work (Marchand, Blanc, & Beauregard, 2017). Although the study did find that non-work stressors such as marital status and having a child at home were associated with self-reported heart disease (Marchand et al., 2017). These results show that it might be necessary to include non-work stressors alongside work stress to be more inclusive of other types of chronic life stress as well. One of the drawbacks of having results from only one longitudinal study is that it can provide a biased view of the overall relationship between occupational stress and heart disease in Canada. Since data from several international longitudinal studies indicate a temporal relationship does exist between occupational stress and CVD, we are going to assume that workplace stress precedes CVD development if there is an association found using cross-sectional data in our study.

In conclusion, although research within Canada provides conflicting results to those found internationally, this only highlights the need for further research on the association between workplace stress and CVD amongst the Canadian population. Collectively, a significant number of longitudinal studies show a positive association between occupational stress and abnormal cardiovascular events (Eller et al., 2009; Pejtersen, Burr, Hannerz, Fishta, & Hurwitz Eller, 2015). Individuals with pre-existing cardiometabolic disease and job strain also have a higher risk of mortality than those without job strain (Kivimaki et al., 2018). For the purpose of this research and to account for the limitations of the cross-sectional data used in this study, we will assume that any association found between perceived workplace stress and self-reported heart disease is unidirectional with stress preceding CVD outcome.

2.1.1 Theoretical Models of Workplace Stress or Job Strain

Three different theoretical models aid our understanding of the potential pathways that work environments can lead to developing chronic diseases. Categorizing these types of environments can better provide targeted solutions to address specific workplace stressors. These models may better inform how to reduce workplace stress beyond targeting modifiable risk factors such as smoking and physical activity. As mentioned previously, the models specifically linked to cardiovascular and metabolic impairment are: one, the effort-reward-imbalance (ERI) model (Siegrist et al., 2009); two, the job-demand-control (JDC) model (Häusser et al., 2010); and three, the organizational injustice model (Greenberg, 2010).

To begin, The ERI model proposes that employees perceive their individual efforts should be rewarded appropriately through financial awards, promotion prospects, and job security (Eddy, Wertheim, Kingsley, & Wright, 2017; Siegrist, 2010). Results from both a systematic review and a meta-analysis show that the ERI model has been associated with various cardiovascular abnormalities and the development of CVD (Eddy et al., 2017; Jarczok et al., 2013). A multicohort analysis from 11 European, prospective cohort studies found that individuals with high ERI at work, as opposed to high job stress at work, had an increased risk of coronary heart disease (Dragano et al., 2017). Level of ERI was measured using the standardized 16-item questionnaire, where a high score is associated with elevated risks of poor self-rated health (Siegrist et al., 2009). Numerous longitudinal studies in Canada also show similar results, that higher ERI scores are associated with higher distress and cardiovascular impairment (Aboa-Éboulé et al., 2011; Janzen, Muhajarine, Zhu, & Kelly, 2007). Thus, unfair working conditions and a lack of appropriate rewards (i.e. high effort, low reward) appear to promote a chronic state of emotional distress that can lead to systemic bodily impairment over time (Tsutsumi & Kawakami, 2004). The exact physiological mechanisms by which chronic stress can adversely impact cardiovascular health within the ERI model are little understood, but prospective data indicate this may occur via overactivation of the

HPA axis leading to maladaptive changes in cortisol secretion (Kivimäki et al., 2012; Penz et al., 2019). Blunted cortisol secretion in response to chronic workplace stress indicates maladaptive physiological changes that adversely impact cardiovascular functioning.

It is assumed that high ERI conditions (high effort, low reward) become more prevalent when there is high competition in the labour market and little alternative choice of employment (Penz et al., 2019). As mentioned in Chapter 1, economic conditions in Canada are producing greater income inequality whereby individuals with low SES might have little choice in the types of employment they have (Baker & Solon, 2003; Fortin et al., 2012; Pampel, Krueger, & Denney, 2010). This is because a wider wage gap means that productivity gains in an economy are going to a smaller proportion of the richest at the top, resulting in greater market volatility and less economic growth over time (Yalnizyan, 2013). High income inequality not only diminishes economic growth—affecting job opportunities for those at the lower end of the spectrum—but also disturbs the social cohesion of a country, leading to higher social tension in communities (Conference Board of Canada, 2011). Poor economic conditions can also lead to adoption of unhealthy behaviours and higher chronic disease risk (Pampel et al., 2010). Thus, a wider income gap might result in higher ERI levels, indicative of higher workplace stress and cardiovascular abnormalities.

On the other hand, the job-demand-control model focuses on the amount of autonomy one has over workloads and job tasks (Chandola, Heraclides, & Kumari, 2010; M. Elovainio et al., 2006; Jarczok et al., 2013). In this model, jobs that exhibit high demand and low control are referred to as "high strain jobs" and are shown to result in stress-related disease outcomes (Chandola et al., 2010). Similar to ERI, the JDC model has been associated with impaired cardiovascular functioning and coronary artery disease (Soderberg, Rosengren, Hillstrom, Lissner, & Toren, 2012). Although longitudinal studies involving JDC are lacking in Canada, results from cross-sectional data show that high strain jobs are associated with higher self-reported stress levels (Schechter, Green, Olsen, Kruse, & Cargo, 1997). A review of longitudinal and cross-sectional studies internationally also report a positive association between high strain jobs and high stress levels (De Lange, Taris, Kompier, Houtman, & Bongers, 2002; Häusser et al., 2010). A systematic review found that a majority of studies used the job content questionnaire to identify high-strain jobs, and thus results are comparable across studies (Alves, Hökerberg, & Faerstein, 2013). In line with effort-reward-imbalance, the JDC model also shows dysregulation of the HPA axis resulting in either hyper or hyposecretion of cortisol (Joseph & Golden, 2017; Marchand, Juster, Durand, & Lupien, 2016). Although we explain the physiological embedding of stressful environments in greater detail below, it is important to note that abnormal HPA-axis functioning can affect systemic imbalances in immune, metabolic, and cardiovascular functioning (Ganster & Rosen, 2013).

The interesting aspect of the JDC model is that it can include unemployment as creating conditions of low control and increasing work demands for the jobs left available in the labour market. Macroeconomic changes during economic recessions would then be seen as increasing job strain for those who face challenges with unemployment or increasing job demands (De Lange et al., 2002; Fenwick & Tausig, 1994). In the JDC model, changing economic conditions that promote competition in the labour market can potentially create a greater number of "high strain jobs". Some researchers relate this to economic globalization which is changing working conditions in industrialized countries to produce more jobs with higher work demands and thus higher stress (Schnall, Dobson, & Landsbergis, 2016). The many unintended consequences of globalization include: more precarious work and income inequality, lower unionization rates, and the outsourcing of manufacturing jobs. All of these factors together might be increasing stress levels for those within lower SES and contributing to the existing health disparities in Canada (Schnall et al., 2016).

Lastly, the organizational injustice model focuses on perceptions of fair treatment in the workplace. This model takes interpersonal work relationships and ethics into account, and focuses on factors such as polite and considerate treatment by authority figures at work (Jarczok et al., 2013). Studies have shown that those who experience more injustice at work have lower heart rate variability (HRV) and cardiac dysregulation (M. Elovainio et al., 2006). The physiological response under increased organizational injustice also shows impairments of cardiovascular functioning through increased blood lipids, myocardial infarctions, and development of coronary heart disease (Marko Elovainio et al., 2006; Greenberg, 2010). Data collected from 4,591 employees from a Canadian government organization showed that psychological strain, as measured by the general health questionnaire, was higher across multiple injustice variables (Francis & Barling, 2005). Forms of injustice assessed within the study included interactional injustice (treating subordinates with kindness and respect), procedural injustice (fair organizational policies and protocols), distributive injustice (fair compensation), and job insecurity (Francis & Barling, 2005; Tepper, 2001). Organizational injustice research indicates that distributive injustice may be the most fundamental source of stress amongst employees (Greenberg, 2006), which is especially concerning within Canada due to the recent rise in income inequality. Under the organizational injustice model, lower wages within the labour market could indicate high stressful conditions for a greater number of employees.

Researchers are aware that there is undoubtedly some overlap between the above-mentioned theoretical models. For example, distributive injustice can also be categorized as an imbalance between effort and reward (Greenberg, 2010). Thus, it is important to understand the different ways in which these models categorize stressful work environments, but also realize that any workplace that causes distress can likely have components of organizational injustice, high-demand low-control, and high-effort low-reward, present together. These models provide a sound way to categorize stressful workplace environments and help us understand how our occupations can potentially create chronic stress in the body, leading to poor health outcomes over time.

2.1.3. Etiology of Physiological Stress and Chronic Disease Outcome

The physiological embedding of workplace stress as a risk factor for developing cardiovascular abnormalities and CDs is complex and multifaceted. There can be multiple pathways through which chronic stress might lead to physiological impairment. This review will focus on the three listed below.

1. Workplace stress can indirectly lead to the adoption of unhealthy behaviours, including smoking, reduced physical activity, and poor nutrition intake, which are all implicated in the development of CVD and T2D (Kivimaki et al., 2018; Roca, 2015; Tsai, 2012; Yusuf et al., 2004).
2. Chronic stress contributes to allostatic load via overactivation of the hypothalamic-pituitary-adrenal (HPA) axis, whereby the body releases excess cortisol leading to inflammation and degradation of physiological functions (Juster, McEwen, & Lupien, 2010; McEwen, 2005).
3. Chronic stress can directly over-activate the autonomic nervous system (ANS), which increases vulnerability to cardiovascular and metabolic abnormalities (Chandola et al., 2008; Jarczok et al., 2013; Lampert et al., 2016).

Unhealthy Lifestyle Behaviours as Risk Factors

The indirect role of workplace stress leading to the adoption of unhealthy behaviours has been studied extensively. Maladaptive behavioural changes such as increased alcohol intake and smoking, reduced physical activity, and poor dietary habits can be a means of coping with increased demands at work (Hamer, Molloy, & Stamatakis, 2008; Tsai, 2012). High strain jobs and high ERI occupations have been associated with an increased risk of smoking prevalence and intensity (Hellerstedt & Jeffery, 1997; Kouvonen, Kivimäki, Virtanen, Pentti, & Vahtera, 2005; Rugulies, Scherzer, & Krause, 2008). In addition, high job strain is also associated with binge eating, physical inactivity, and heavy alcohol intake (Gralle et al., 2017; Heikkilä et al., 2012; Rugulies et al., 2008). Identifying risk factors for chronic diseases was seen as a way to combat disease incidence and thus became the norm in clinical and epidemiological studies.

The InterHeart study, conducted across 52 countries, aimed to identify specific risk factors for coronary heart disease using a case-control study design (Yusuf et al., 2004). The authors found that current smoking status and higher LDL cholesterol (i.e. bad cholesterol) had the strongest association to cardiac events, along with history of diabetes, hypertension, and abdominal obesity (Yusuf et al., 2004). Factors that protected against the development of CHD included daily consumption of fruits and vegetables, physical exercise, and low consumption of alcohol (Yusuf et al., 2004). Combating these known risk factors became especially important for employers as healthy employees are more productive and less absent from work (Bhojani, Tsai, Wendt, & Koller, 2014; Chen et al., 2015). More employers started to encourage healthy lifestyle behaviours to reduce medical and disability costs associated with cardiometabolic diseases (Lucini, Solaro, Lesma, Gillet, & Pagani, 2011; Young, 2006). As a result, workplace wellness programs target some aspect of improving lifestyle behaviour choices, but may fail to address the root causes: heavy workloads, long work hours, and high strain work environments (Carr, Kelley, Keaton, & Albrecht, 2011; Song & Baicker, 2019).

Physiological Embedding of Stress

HPA-axis and cortisol secretion

In addition to behaviour risk factors, psychosocial stress can directly cause physiological changes over time. One important pathway is via overactivation of the HPA axis in which excess glucocorticoids—particularly cortisol—are released in the body (Brotman, Golden, & Wittstein, 2007). Cortisol acts to increase blood pressure, inhibits immune response, and reduces insulin sensitivity, which can all have detrimental effects on cardiovascular and metabolic functioning

(Brotman et al., 2007). These circulating glucocorticoids can result in thicker blood viscosity, leading to impairment of endothelial function—the lining of the blood vessels (Bacon et al., 2006; Brotman et al., 2007). A blunted cortisol response is also found under chronic stress conditions, as seen with employees reporting high effort-reward-imbalance conditions. This cortisol response in the body is also maladaptive and has been associated with an increased risk of coronary calcification (hardening of arteries) and coronary artery disease (Matthews, Schwartz, Cohen, & Seeman, 2006; Nijm, Kristenson, Olsson, & Jonasson, 2007). As such, stress-induced changes to cardiovascular physiology may result in increased susceptibility to CVD under stressful workplace conditions (Brotman et al., 2007; Strike, Perkins-Porras, Whitehead, McEwan, & Steptoe, 2006). Surprisingly, these changes in coronary physiology have been found even after adjusting for lifestyle behaviours (Brotman et al., 2007). Thus, it might be important to go beyond simply promoting healthy behavioural interventions and understand the underlying mechanisms of how stress impacts biological functioning.

Autonomic nervous system overactivation

Along with excess glucocorticoids in the blood, the body will also have higher levels of circulating catecholamines—predominately epinephrine—through activation of the autonomic nervous system (Brotman et al., 2007). Epinephrine will act to increase heart rate and arrhythmias, decrease heart rate variability (HRV), and also lead to endothelial dysfunction (Brotman et al., 2007). ANS dysregulation resulting in chronic low-grade inflammation in the body is known to be associated with metabolic syndrome (obesity, insulin resistance, hyperlipidemia, and hypertension) which increases the risk of developing heart disease and type II diabetes (Elkhatib & Case, 2019; Monteiro & Azevedo, 2010; Paoletti, Bolego, Poli, & Cignarella, 2006). Decreased HRV has been a reliable measure of cardiac abnormalities induced by job strain (Jarczok et al., 2013). The type of work environments that induce changes in HRV have been linked to all three theoretical models discussed previously: ERI, JDC, and organizational injustice (Hintsanen et al., 2007; Jarczok et al., 2013; Kivimaki et al., 2002). All models show that psychosocial work environments can lead to abnormal changes in cardiac and metabolic physiology which may not be improved by adopting healthy lifestyle behaviours. Thus, a deeper understanding of the effects of social risk factors is required to prevent maladaptive physiological changes in the first place.

2.1.3 Socioeconomic Status: Income, Education Level, and Occupational Status

Occupational Status

Researchers began uncovering occupational status as a social determinant of health almost five decades ago, with the now famous Whitehall studies in London finding an association between occupational status and coronary heart disease (Marmot et al., 1991). Since then, multiple studies from numerous countries have shown an inverse-graded relationship between socioeconomic status and cardiovascular morbidity and mortality (Cooper et al., 2010; Pickering, 1999). It is important to note that this relationship exists even after adjusting for behavioural risk factors such as smoking and physical inactivity (Cooper et al., 2010). Thus, socioeconomic factors may be an important aspect in the association between workplace stress and outcomes of heart disease.

Some international studies have found a stronger association between CVD and one aspect of SES in particular—occupational status. For example, Wiernik et. Al. (2018) estimated a 10-year coronary heart disease risk among a cohort of 35,205 working individuals and found that those within a lower SES group had a higher risk of CHD, especially when belonging to a lower occupational status. This finding is consistent with those from Cooper et. Al. (2010) who assessed a type of endothelial dysfunction that precedes CVD, known as flow-mediated dilation (FMD). The authors found that subjective socioeconomic status, rather than objective measures of SES, had stronger associations with FMD (Cooper et al., 2010). This is suggestive of the tremendous influence one's perception of social position might have on biological health and is especially important to consider in light of the increasing income gap in Canada. In addition, certain types of employment may also carry a higher risk of developing cardiovascular abnormalities. A study conducted in northern Italy followed two cohorts for an average of 13 years to ascertain incidence of coronary events (Ferrario et al., 2011). The authors found that incidence of CHD was highest amongst manual workers, followed by administrators and professionals, and lowest in those who were self-employed (Ferrario et al., 2011). Likewise, hospitalisation for a certain type of cardiovascular abnormality known as venous thromboembolism (VTE) was higher in blue collar workers, farmers, and unemployed individuals from a Swedish sample of 43,063 individuals (Zoller, Li, Sundquist, & Sundquist, 2012). Thus, occupational position might be an important aspect of SES that can lead to cardiovascular morbidity.

Although research within Canada on occupational type and chronic disease outcome has been scarce, a recent study used the CCHS (2001-2014) to look at trends over time between occupation type (management/arts/education, business/finance, sales/service, trades/transportations, and primary industry/processing) and heart disease (Nowrouzi-Kia, 2018). The authors found significantly different results of self-reported heart disease and occupation types between the years 2003 and 2014. Compared to management occupations, trades/transportation/equipment occupations reported a significantly higher odds (OR=1.44 and OR=1.52) of heart disease during 2009 to 2010 and 2013 to 2014, respectively. Although the data are not longitudinal, it is concerning that we see an increased odds of reporting heart disease, from 44% higher odds to 52%, within just three years. Canadian data shows that overall occupation type might be an important aspect of socioeconomic status in determining heart disease outcome.

Income Level

On the other hand, studies have focused solely on income rather than a multidimensional measure of SES as a sole predictor of chronic disease morbidity. A longitudinal study that captured income changes over time grouped 8,987 study participants under either household incomes that decreased >50%, increased >50%, or changed less than 50% over a mean period of 6 years. The authors found those who experienced a significant income loss (>50%) had a 30% higher risk of incident CVD compared to those whose income remained unchanged in that time (Wang et al., 2019). Similarly, Lynch et al. found that men with high demands and low income had higher cardiovascular atherosclerosis than those with low demand and high-income jobs (Lynch, Krause, Kaplan, Salonen, & Salonen, 1997). Along with having lower monetary rewards from work, individuals with low income may experience higher psychosocial stress in life which can further deteriorate cardiovascular health. As such, when researchers accounted for psychosocial stress from household responsibilities, ambulatory blood pressure readings were higher in individuals who reported low income (Thurston, Sherwood, Matthews, & Blumenthal, 2011). Low income status is assumed to serve as an indicator of environmental stressors (crime and pollution), health behaviours (poor dietary habits), and weakened social supports (Mobley et al., 2006). In a study on women living with low income, researchers found that neighbourhood affluence was significantly associated to CHD risk, while controlling for other aspects of SES including education level (Mobley et al., 2006). Thus, we can see how complicated the relationship between SES and heart disease is, whereby both income and occupational position may act individually to impact cardiovascular health.

Due to limited longitudinal data in Canada, researchers again used 4 cycles of the CCHS between 2000 and 2008 to show that there is indeed an inverse graded relationship between income and heart disease outcomes (Lemstra, Rogers, & Moraros, 2015). Household incomes of $29,999 or less showed significantly higher odds (92%) of reporting heart disease than those with a household income of $80,000 or more. This association may be mediated through high blood pressure, which was significantly higher in the low-income group than in the high-income group. As mentioned previously, there was also a higher prevalence of smoking behaviour within the low income group than among those with household incomes of $80,000 or more (Lemstra et al., 2015). The authors showed that household income was independently associated with outcomes of heart disease even when smoking and physical activity status were controlled. This indicates that income level may be associated to heart disease outcomes even in the absence of traditional disease risk factors. Similarly, longitudinal data from the National Population Health Survey (NPHS) showed that heart disease increased significantly by 27% in the lowest income category, compared to a 6% increase in the highest income group (Lee et al., 2009). These results occurred at the same time as the prevalence of smoking decreased from 24% in 1994, to 18% in 2005. Therefore, income seems to be a strong independent risk factor for heart disease outcomes amongst the Canadian population, even when disease risk factors are accounted for.

Educational Attainment

Some studies indicate that education level might be the most important dimension of SES in relation to chronic disease outcomes. A recent study on socioeconomic status and cardiovascular disease risk in 20 low, middle, and high income countries found that education level was the strongest predictor of major CVD and all-cause mortality compared to other indicators of SES (Rosengren et al., 2019). The largest difference in death rates for CVD between the lowest and highest education levels was found in low and middle income countries, where the disparity between different education levels are a lot higher (Rosengren et al., 2019). Likewise, researchers in Greece found that those from lower education groups have a two-fold higher risk of all-cause mortality than their intermediate and higher education counterparts (Notara et al., 2016). Acute coronary syndrome was also more common amongst those from a lower education group than those with higher education privileges (Notara et al., 2016). This observed difference may be partly due to engaging in healthy lifestyle behaviours, as those from higher education backgrounds are more likely to be physically active and follow a healthy diet (Notara et al., 2016). However, a strong relationship between diet quality, BMI, and education levels in men was only found in middle and high-income countries (Di Cesare et al., 2013). Thus, we can see that education level, along with income and occupation type, might have an independent impact on outcomes of heart disease.

Research on the association between education levels and heart disease in Canada has been limited to cross-sectional data. Results from the CCHS (2011-2012) found that levels of multimorbidity increased in households with lower education levels (Roberts, Rao, Bennett, Loukine, & Jayaraman, 2015). Those who reported multiple chronic diseases, including self-reported heart disease and diabetes, were more likely to have less than a high school education. The second highest prevalence of multimorbidity reported by Canadians was a triad of diabetes, heart disease, and asthma. Once models adjusted for all variables, only household income remained a significant dimension of SES associated with multimorbidity (Roberts et al., 2015). Although the authors did not mention how social deprivation was measured, the study also found that social deprivation had 3.7 times higher odds of multimorbidity in the overall population. These Canadian results corroborate those found internationally, that the onset of multimorbidity occurred 10 to 15 years earlier in persons livings in the most deprived areas compared to those living in affluent areas (Barnett et al., 2012). Research so far indicates that each individual aspects of SES may independently lead to cardiometabolic disease outcomes, and hence each aspect should be accounted for in our analysis.

Diabetes

2.4. Effect of Workplace Stress or Job Strain on Metabolic Health

T2D is a metabolic disorder resulting from hyperglycemia caused by insulin resistance (Alberti & Zimmet, 1998). Globally, there has been a rapid increase in diabetes mellitus which has led to interventions targeting diabetes risk factors (Morikawa et al., 1997). Despite these efforts, the incidence of type II diabetes continues to increase due to the complexity of the environmental context that exacerbates insulin sensitivity. Earlier in the literature review, we discussed autonomic and HPA dysregulation leading to cardiometabolic dysfunction over time. This means that diabetes can also be a risk factor for CVD due to shared physiological pathways. Psychosocial stress can thus induce changes in metabolic physiology through similar mechanisms involved in cardiovascular dysregulation, including overaction of the HPA axis and both micro and macrovascular complications (Alberti & Zimmet, 1998; Brotman et al., 2007). To avoid repeating information, the physiological embedding of stress as metabolic dysfunction can be understood in the same chapter as CVD. We will instead review results from longitudinal studies that establish temporality between stress and T2D outcome. Canadian research will also be discussed to find existing gaps in knowledge.

To establish temporality in the incidence of T2D, we consider longitudinal studies that measured the development of disease outcome over time. A study conducted in Sweden by Novak et al. (2013) followed 7,251 men over 35 years to establish an association between self-perceived stress and incidence of T2D. The authors found that men who reported higher levels of stress were more likely to develop type II diabetes over time than men with no or periodic stress (Novak et al., 2013). Similarly, studies conducted with women in London have reported an association within the Whitehall II cohort, where data analyzed from 1991 to 2004 showed double the risk of developing T2D for those who scored high on the job strain questionnaire (Heraclides, Chandola, Witte, &

Brunner, 2009). These findings support our previous discussion on the job-demand-control model which showed an independent association between high self-reported stress via high job strain and cardiovascular impairment (Chandola et al., 2010; Häusser et al., 2010). Findings on chronic stress leading to higher incidence of diabetes are similar to CVD due to shared physiological pathways. This is further reinforced by results found from pooling 13 European cohort studies that measured job strain at baseline and then followed up for incident type II diabetes cases (Nyberg et al., 2014). Even after controlling for lifestyle factors, researchers found that job strain was positively associated with an increased risk of developing T2D. This indicates that the association between stress and T2D may also be independent of behaviour risk factors.

Although research within Canada is lacking on workplace stress and incident T2D, longitudinal data from Ontario shows that over nine years, incidence of T2D was higher amongst only women—not men—who reported having low control on the job (Smith, 2012). Due to a lack of longitudinal health survey data in Canada, this study used data linkage to provincial health records known as Ontario Health Insurance Plan (OHIP). Diabetes outcome was determined based on hospital admission with a diagnosis or a physician diagnosis within 2 years. Surprisingly, the authors found no association between high job strain and incident diabetes within men and women. Conflicting results from longitudinal Canadian data and studies conducted internationally might exist due to a lack availability of high-quality longitudinal survey information. On the other hand, cross-sectional data tells a different story amongst women living in Canada. Analysis of the CCHS (2007-2008) shows that women who reported being extremely stressed on most days of their lives had 44% higher odds of reporting obesity than those who were not stressed at all (Chen & Qian, 2012). Obesity is a well-known risk factor for both cardiovascular diseases and type II diabetes. Thus, increased odds of having obesity can mean an increased risk of developing diabetes mellitus (Al-Goblan, Al-Alfi, & Khan, 2014; Sharma & Lau, 2013).

As mentioned above, low control on the job can cause metabolic impairment over time because it might induce chronic stress in the body. Thus, this study is going to assume that workplace environments which create chronic stress conditions might lead to the development of T2D over time. Evidence for certain types of workplaces that induce insulin resistance are found under conceptual frameworks of the job-demand control model and effort-reward imbalance (Heraclides et al., 2009; Kumari, Head, & Marmot, 2004). Psychosocial work environments with either low control and high demand, or low reward imbalance can cause chronic stress and lead to maladaptive changes in insulin sensitivity. Due to similar findings between type II diabetes and CVD, it is safe to assume for this research that these types of workplace environments can lead to outcomes of either T2D or CVD. This is why our understanding improves if we study both chronic diseases simultaneously and see if the association holds true for both CD outcomes.

2.4.1. Socioeconomic Status: Income, Education Level, and Occupational Status

Along with the workplace environment, it is also important to understand how the economic environment can impact metabolic dysfunction. Socioeconomic status might be independently associated with insulin resistance even after accounting for other possible risk factors (Novak et al., 2013). In terms of occupation level, Kumari et al. (2004) was able to show a reverse gradient association between occupational status and T2D even after adjusting for effort-reward imbalance. This shows that socioeconomic status might be associated independently to type II diabetes even in the absence of stressful work environments. Thus, it would be beneficial to understand which particular aspects of socioeconomic status—occupational status, income, or education level—are more strongly associated with the development of T2D. We discuss the role of socioeconomic status in exacerbating insulin sensitivity in greater detail below. Canadian research is also highlighted where possible, although longitudinal data showing incident diabetes mellitus is limited.

Beginning with occupational status, a ten-year follow-up from 1983 to 1993 tracked the incidence of T2D among male workers at a zipper and aluminum factory in Japan (Morikawa et al., 1997). Researchers grouped the employees into five different categories including managers, technical workers, clerical workers, workers in transport, and laborers; they found that workers in transport had the highest incidence of T2D compared to all other occupation groups (Morikawa et al., 1997). Similar findings were seen amongst occupational groups of women who served as British civil servants during the Whitehall II cohort study (Heraclides et al., 2009). Heraclides et al. (2009) categorized occupational grades into three groups including administrative (which included 7 grades of salaries), executives (including senior executive officers and professional and technical staff receiving similar salaries), and clerical (including clerical and office support salaries). Female staff members who belonged to the clerical group had higher odds of developing T2D (Heraclides et al., 2009). This study included 12 occupational grades based on salaries which shows how the effects of income can be considered along with occupational status. Various aspects of SES may thus be intertwined and assessing the concept of socioeconomic status together may be more important than analyzing individual parts alone.

Information on occupational status and incident diabetes in Canada is lacking behind other countries, but pooling CCHS data across 14 years from 2001 to 2014 has allowed for some insight into “longitudinal” trends in the Canadian population. It is important to note that this type of analysis still does not provide us with information on incident T2D cases, however, the authors found that across five years (2008-2011 and 2013), type of occupation level was significantly associated to disease outcome. Those who belonged to finance, business, administration; trades, transportation, and equipment; and primary industry, processing, manufacturing, and utilities sectors were more likely to report having diabetes outcome than occupations in management, sciences, health, education, arts, and culture (Li & Nowrouzi-Kia, 2017). Longitudinal data over 7 years in Manitoba showed that those who developed type II diabetes may face further discrimination in employment status and income due to complications from the disease (Kraut, Walld, Tate, & Mustard, 2001). This indicates that the relationship between occupation status and type II diabetes may be complicated and cyclical in nature where greater physiological deterioration may impact occupation status and vice versa.

A second aspect of SES—income—might improve health status by indirectly affecting health behaviour choices such as improving access to better nutrition, and directly decreasing bodily cortisol by reducing finance-induced stress (Marks, 2007). To determine if this association exists in Canada, a cross-sectional study used data from the CCHS between 2000 and 2008 and found a statistically significant association between low income and prevalence of type II diabetes (Bird et al., 2015). Using a sample of 27,090 residents in Saskatchewan, researchers found that household income was strongly associated to T2D status, even after adjusting for other risk factors such as high blood pressure, being overweight or obese, and being physically inactive (Bird et al., 2015). It should be noted that although education was measured in the survey, it was not found significantly associated with T2D status (Bird et al., 2015). This is concerning because although the Canadian population is becoming more educated, income disparities between low and high income households continue to grow (Institute for Research on Public Policy, 2017; OECD, 2008, 2011, 2015; Statistics Canada, 2017). Another Canada-wide study using the same dataset in 2005 show a similar association between income and T2D (Dinca-Panaitescu et al., 2011). The authors found that the prevalence of T2D was four times higher in the low income group compared to the high income group, and remained significant even after adjusting for other risk factors such as housing, BMI, and physical activity (Dinca-Panaitescu et al., 2011). Therefore, Canadian data suggest that low income is associated with prevalence of T2D even after adjusting for risk factors including physical activity levels, BMI, hypertension, and education levels.

To deepen our understanding through longitudinal results, we turn to studies conducted globally that measured the relationship between income and incident type II diabetes cases. Over a

5-year follow-up in 600,662 individuals free from diabetes in Taiwan, researchers found that those who had low income even in universal healthcare had a 50% higher risk of developing T2D in males and females than their middle-income counterparts (Hsu et al., 2012). Separate studies on only women in the USA show similar results, where African American women who had a household income <$15,000 had 57% higher incidence of type II diabetes than those who were from household >$100,000 (Krishnan, Cozier, Rosenberg, & Palmer, 2010). The Black Women's Health Study had a follow-up period of 12 years and 3,833 incident diabetes cases to report from. They found that BMI attenuated this relationship to only a 20% higher incidence for the low-income group. A similar trend was seen amongst the NANES I Epidemiologic Follow-up Study (NHEFS) that collected incidence diabetes cases until 1992 (Robbins, Vaccarino, Zhang, & Kasl, 2005). Authors found an inverse association between income level and diabetes incidence in both men and women when adjusting for age and race/ethnicity. However, the association was attenuated when further confounders, including body size, alcohol and tobacco use, physical activity, and diet, were added to the models. In women, those with incomes five times higher than the poverty level saw 40% lower incidence of diabetes (HR = 0.60). In men, those with income greater than five times the poverty level saw a 56% lower risk of developing type II diabetes (HR=0.44). Additional controls did not attenuate the association in men as significantly as for women (Robbins et al., 2005). It should also be noted that occupation status was found not associated with incident T2D in this study. Therefore, income level proves itself a useful aspect of SES in predicting type II diabetes outcome, both globally and within Canada.

The final aspect of socioeconomic status we will discuss in relation to type II diabetes outcome is education level. Several existing studies have shed light on the effect of educational attainment and poor health outcomes, and information from multiple studies can better inform our understanding. To begin, results from larger international studies will be discussed prior to assessing Canadian studies. From the UK, a longitudinal study analyzed various aspects of socioeconomic position (SEP), including childhood SEP, education, occupational position, income, and subjective social status (SSS), and found that all aspects of SEP were associated to incidence of T2D; however, only childhood SEP and education remained statistically significantly after adjusting for other risk factors (Demakakos, Marmot, & Steptoe, 2012). In addition, a large study conducted in eight Western European countries found that participants from lower educational backgrounds had higher risk of developing T2D even after adjusting for physical activity, smoking status, and macronutrient intake (Sacerdote et al., 2012). The researchers followed the study participants for an average of 12 years and were able to track incident cases of T2D by self-reports of either medical doctor diagnosis or medication use (Sacerdote et al., 2012). To combat the issue of different education standards across countries, for example the percentage of the population that was enrolled in secondary school, the researchers were able to assign relative scores of education. They found that the relationship between T2D and low education levels stayed robust even after adjusting for relative education level and behavioural risk factors (Sacerdote et al., 2012). Along with a higher incidence of T2D, the lower education groups also had higher BMI values, were more likely to be smokers, alcohol drinkers, and physically inactive men and women (Sacerdote et al., 2012). Thus, international studies with greater amount of data find stronger associations between education attainment and type II diabetes outcome.

There is again conflicting evidence between what data are showing globally and what we find in Canada. A previously mentioned study conducted by Bird et al. showed that amongst residents of Saskatchewan, education was not significantly associated with T2D status in the presence of other risk factors (Bird et al., 2015). Although the evidence found is weaker due to the cross-sectional nature of the data and incidence of type II diabetes is not ascertained, the only socioeconomic variable the authors found that remained significantly associated to diabetes mellitus was having a household income of $29,999 or less per year (OR = 1.63), along with only five other variables including: having high blood pressure (OR = 3.26), visible minority or cultural status (OR = 2.17), being overweight or obese (OR = 1.97), male gender (OR = 1.76), and being physically inactive (OR = 1.15). Due to their findings, the authors do recognize that preventative strategies for diabetes have grossly focused on disease risk factors instead of underlying issues such as social and economic determinants. On the other hand, national findings using the first cycle of the CCHS (2000-01) tell a different story than provincial data by Bird et al. Researchers were able to reproduce results from a smaller study that used the second cycle of the National Population Health Survey (NPHS) collected from 1996 to 1997. NPHS data included 39,021 study participants over the age of 40 and showed that in both males and females, the prevalence of diabetes increased within lower levels of educational attainment (Tang, Chen, & Krewski, 2003). The first cycle of the CCHS on a national level also showed that the prevalence of type II diabetes was highest among the least educated—those who did not complete high school (Dasgupta, Khan, & Ross, 2010). National-level cross-sectional data are corroborating findings from studies conducted internationally that show an association between lower levels of education and higher outcomes of type II diabetes.

A meta-analysis study generates a stronger form of evidence through pooling data from several prospective cohort studies. Published and unpublished studies from Europe, USA, Japan, and Australia showed that amongst 222,120 men and women, all aspects of low socioeconomic status were associated to higher incidence of type II diabetes (Kivimäki et al., 2014). A larger meta-analysis study conducted in both high income and low income countries showed that lower levels of all three aspects of SES were significantly associated to an increased risk of developing T2D (Agardh, Allebeck, Hallqvist, Moradi, & Sidorchuk, 2011). Although there may be some variation in significance amongst studies from one aspect of SES to another, cumulative information from multiple studies indicates the importance of using all aspects of SES as opposed to only one dimension when analysing the development of T2D (Agardh et al., 2011). Thus, our literature review concludes that including each aspect of SES will be important in discerning the true effect of socioeconomic status on cardiometabolic outcomes.

2.5. Summary

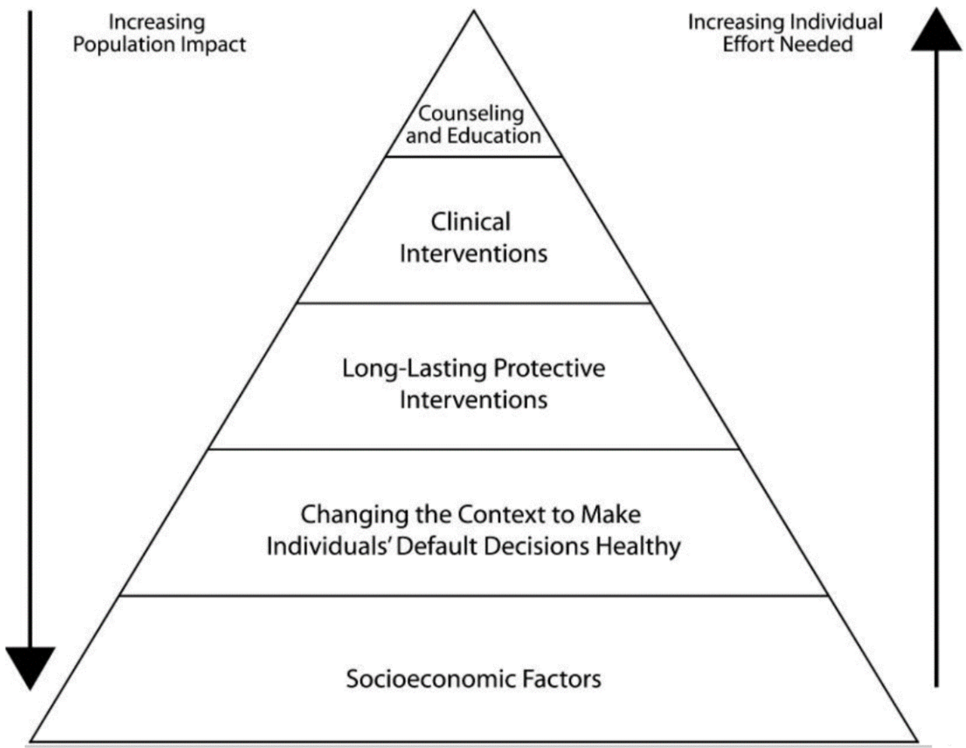
This literature review demonstrates the lack of information regarding the effects of both SES and workplace stress on cardiometabolic diseases in Canada. Although researchers have been able to show an inverse-graded relationship between SES and chronic disease outcomes in Canada, understanding this relationship in relation to workplace stress levels remains understudied. As a result, it is important to first determine the relationship between the individual effects of SES and self-reported workplace stress on each disease outcome using data from the CCHS. We will conduct further analysis on the combined effects of non-traditional risk factors on heart disease and diabetes outcomes.

2.6. Conceptual Framework: Health Impact Pyramid

The health impact pyramid is a conceptual framework that outlines the potential for public health interventions to improve the health of a population (Frieden, 2010). Figure 1 shows the greatest level of impact at the base of the pyramid with interventions that address socioeconomic determinants of health (Frieden, 2010). Higher SES is attributed to changing the environment surrounding the individual whereby the healthier choice becomes the easier choice, minimizing individual effort. The framework also shows that clinical interventions and health education are the least impactful, as they require greater individual effort and cannot target broader segments of the population (Frieden, 2010). As a result, this research will highlight factors that are outside of an individual's control, including socioeconomic status and workplace environment, in an effort to inform interventions beyond individual level effort.

Within this framework, an individual's behaviour is not viewed as solely his or her responsibility. Instead, it is determined by the interaction between the individual and the environment—calling for a change in both (Richard, Gauvin, & Raine, 2011). A broader approach is therefore necessary to address the immense complexity of public health issues that comprise of individual, social, cultural, and global influences on health behaviour choices (McLaren & Hawe, 2005; Richard et al., 2011). Figure 1 shows the health impact pyramid below with various types of interventions (Robinson, 2008).

Figure 1 - Health Impact Pyramid:



(Frieden, 2010)

This framework helps to explain why previous public health interventions might not have been successful in combating complex health problems. Due to the recent change in addressing CDs, the objective now is to take a broader perspective to include the social and economic environment surrounding unhealthy behaviours. Thus, we aim to move past individual and behavioural factors and account for organizational and societal determinants of chronic diseases to better inform public policy in the future. To further understand the true impact of workplace environments and socioeconomic status in exacerbating CD outcomes, this research study controlled for behavioural factors such as smoking status, alcohol intake, physical activity levels, and nutrition intake.

2.5. Study Objectives

Heart Disease and Diabetes

We had two objectives for this research: first, we wanted to understand if socioeconomic status (income, education level, and occupational position) and self-reported perceived stress levels are both significantly associated with self-reported heart disease and diabetes in Canada when controlling for known confounders, specifically age, sex, race/ethnicity, and BMI. If both SES and workplace stress were found significantly associated to outcomes of CVD and T2D, we would then adjust for additional variables by including traditional behaviour risk factors (physical activity, smoking status, alcohol consumption, and fruit and vegetable intake) to understand if there is any attenuation of the relationship due to disease risk factors.

Second, we wanted to understand the combined effects of SES and workplace stress levels on outcomes of CVD and T2D. To this end, we measured two types of interaction effects between both SES and workplace stress. The first was via multiplicative interaction which we determined by adding interaction terms to the logistic regression model. The second, less common measure of joint effects, was through additive interaction. If a positive joint effect is found, future studies should consider using longitudinal data to determine the exact pathways that exist between SES, workplace stress, and CD outcomes through mediation analysis.

	Figure 2 – Research Questions
Question 1a	Are socioeconomic status (income, education level, and occupational status) and self-reported work stress levels significantly associated with Cardiovascular Disease/Type II diabetes outcome, when controlling for age, sex, ethnicity, & BMI?
Question 1b	Is there a significant association even after adjusting for disease risk factors such as physical activity, healthy diet, smoking status, and alcohol consumption?
Question 2	What are the combined effects of self-reported workplace stress and SES on both CD outcomes (synergistic: the joint effect is higher than individual effects or antagonistic: the joint effect is less than the individual effects)?

Chapter 3.0. Methods

This research study used data collected by Statistics Canada from their annual cross-sectional, national level population health survey known as the Canadian Community Health Survey (CCHS). Information from combined years 2015 and 2016 was used to provide a larger sample size for our analysis. Multivariate logistic regression models using stepwise backward selection identified factors significantly associated ($p<0.05$) with self-reported heart disease and diabetes. Survey weights were applied to account for oversampling and under sampling of specific health regions. In this chapter, we will provide more in-depth information about the data source used, the general approach used to answer our research questions, and the exact variables used in our analysis from the CCHS 2015-2016.

3.1. Data Source: Canadian Community Health Survey

Data Collection

This study conducted secondary data analysis using the 2015-16 cycle of the CCHS, which gathered information on health status, healthcare utilization, and health determinants of the Canadian population (Statistics Canada, 2016b). The sample consisted of 78,023 voluntary participants excluding persons living on First Nations reserves and other Aboriginal settlements in the provinces, full-time members of the Canadian Forces, institutionalized population, children 12 to 17 years old living in foster care homes, and persons living in the Quebec health regions of Région du Nunavik and Région des Terres-Cries-de-la-Baie-James. This survey is still considered representative of 98% of the Canadian population with coverage varying in northern regions—94% coverage in Yukon, 96% in the Northwest Territories, and 93% in Nunavut (Statistics Canada, 2016b).

Data were collected voluntarily from study participants using computer assisted personal and telephone interviews. Respondents were initially allowed to provide an interview in English or French, but Statistics Canada Regional Offices allowed interviewers to conduct interviews in languages they were proficient in (Statistics Canada, 2016b). Because household variables are used in this research study, it is important to detail the two-step process of how this information was collected. First, the interviewer was given a complete list of people living within the household (household response), and then the selected person within the household was interviewed (person response) (Statistics Canada, 2010). The calculation of the household weight was then applied using the individual response to represent the household. Information collected during the interviews was linked to personal tax records (T1, T1FF, or T4) along with tax records of all household members; thus, household income data were imputed via linkage of records (Statistics Canada, 2016b).

Sample Weighting

The aim of the CCHS is to provide reliable estimates of the 110 health regions it surveys in Canada. A multi-stage sample allocation technique is used to ensure equal importance is given to all health regions. The survey design uses stratification and multi-stages of selection to increase representation across all health regions. Due to this, the sample collected is not considered a true random sample and must be adjusted to ensure that selection probabilities do not affect the estimation and variance calculations provided by the survey. A number of statistical techniques can be used to counteract this type of survey design including the techniques used in this study: applying weights to create a representative sample and using bootstrap techniques to improve accuracy of variance estimation (Statistics Canada, 2016b).

To ensure that data collected from the sample are representative of the population, we must incorporate survey weights into our analysis (Statistics Canada, 2010). This is because each person in a sample represents several others who are not included in the survey. For example, if each person from the sample represents 50 persons in the population, then each person will have a weight of 50 applied (Statistics Canada, 2016b). A weighting phase at Statistics Canada calculates the weight associated with each person in the survey and must be applied for any meaningful inference at the population level. Any information determined without the use of weights will provide results representative for the sample, but not the population.

Access to Data

Permission to access the 2015-16 CCHS survey was granted by the Government of Canada upon clearance of a security screening process and the data were primarily accessed at the Southwestern Ontario Research Data Centre (SWORDC) located at the University of Waterloo. Upon swearing to uphold the Statistics Act, I was deemed an employee of Statistics Canada to uphold confidentiality of information. All statistical analyses conducted by me were vetted and released by Dr. Pat Newcombe, the SWORDC Analyst, to ensure confidentiality rules were followed and to prevent identification of any persons.

3.2. General Approach: Multivariate Regression Models

The data analysis involved two steps: the first being exploratory data analysis (EDA) using descriptive statistics (via non-graphical univariate/bivariate/multivariate cross-tabulation) to measure the sample distribution of CD outcomes across all explanatory variables. We conducted univariate analysis for each independent variable. In addition, standard contingency tables were constructed for each categorical variable to determine if sufficient cell counts were reached in each category. Once we determined how the data were distributed and that there were sufficient cell frequencies across all categories of variables, we either collapsed certain categories to form new variables or used the original variable from the CCHS. By having comparable frequencies of data across all categories in each variable, we could ensure there were no outliers and the data analysis provided more accurate conclusions (Komorowski, 2016; Seltman, 2009). EDA also provided a better understanding of the missingness in our data. For example, if only specific variables had a large amount of data missing, then those variables were not used for data analysis. Due to the categorical nature of each variable, chi-square tests determined the level of homogeneity or independence and measured the association between variables (SAS Institute Inc, 2011). A complete list of the type and number of variables examined is detailed in the appendix and missingness for each variable is discussed in section 3.3.

The second step of our data analysis involved using model selection to fit the final logistic regression models. Due to the binary nature of the chronic disease outcome—either the disease is present or absent—a binary logistic regression model was used for outcomes of CVD and diabetes. All explanatory variables used in the model were either already categorical or were transformed into categories (see section 3.3 for more details). To answer part (a) of our first research question, the control variables added to our models were age, gender, race/ethnicity, and BMI. For part (b), we included additional behaviour risk factors: alcohol consumption, fruit and vegetable intake, smoking status, and physical activity status. For our second research question, we added interaction terms to our logistic regression models for multiplicative interaction and transformed multiplicative interaction terms to calculate the additive interaction reported via relative excess risk due to interaction (RERI). To compensate for over-sampling, under-sampling, or disproportionate sampling in the cluster-stratification method of CCHS data collection, only weighted and bootstrapped results were reported (Johnson, 2008). Odds ratios and confidence intervals were reported for each categorical variable of interest, and statistical significance of the main effects of perceived stress and each aspect of SES was determined using $p < 0.05$.

3.3 Variables Used in the Analysis

Outcome Variables

Self-reported heart disease

The CCHS assessed chronic conditions via self-reported variables where respondents would either state "yes", "no", "don't know", "refusal" or "not stated" to having heart disease. Approximately 4.6% of the sample reported having heart disease on the survey, which is half of the estimated prevalence of the condition in Canada (Public Health Agency of Canada, 2017b). An insignificant number of participants reported "don't know", "refusal" or "not stated" (0.2%) and these categories were subsequently deleted from our analysis to convert the outcome into a binary variable. "No" was used as the reference category for our logistic regression model to understand the analysis on all those who reported having heart disease.

Self-reported diabetes

The CCHS assessed chronic conditions via self-reported variables where respondents would either state "yes", "no", "don't know", "refusal" or "not stated" to having diabetes. The survey does not allow for differentiating the type of diabetes but due to the significantly higher prevalence of type II diabetes (approximately 90%), it is safe to use the variable for analysis on type II alone (Public Health Agency of Canada, 2017a). Approximately 6.9% of the sample reported having diabetes on the survey, which is closer to the estimated prevalence of 8.1% in the general Canadian population (Public Health Agency of Canada, 2017b). An insignificant number of participants reported "don't know", "refusal" or "not stated" (0.1%) and these categories were subsequently deleted from our analysis to convert the outcome into a binary variable. "No" was then used as the reference category for our logistic regression model to understand the analysis on all those who reported having diabetes.

Main Explanatory Variables

Self-perceived stress at work

Workplace stress was measured by the following question: "Would you say that most days at work were…?" Participants could answer either "not at all stressful", "not very stressful", "a bit stressful", "quite a bit stressful", extremely stressful", "don't know" and some respondents were categorized as "valid skip", "refusal" or "not stated". Approximately 30.2% of respondents were grouped under "not stated" and therefore we included this category in our analysis. The reason this many respondents did not report work stress may be due to employees hiding mental health issues (Howatt, 2017). The variable for work stress in our analysis was recoded to four categories: not stated, not very to not at all stressful, a bit, and quite a bit to extremely stressful. Perceived life stress was thus used to support the validity of our analysis on self-perceived stress levels. The reference category used for the logistic regression model was "a bit", to better understand the effects of low and high work stress on outcomes of CD.

Perceived life stress

Perceive life stress was measured by the following question: "Thinking about the amount of stress in your life, would you say that most of your days are…?" Participants could answer either "not at all stressful", "not very stressful", "a bit stressful", "quite a bit stressful", "extremely stressful", "don't know" and some respondents were categorized as "refusal". Since only an insignificant amount of participants responded, "don't know" or "refusal" (0.6%), we subsequently removed these categories from our analysis. For our analysis, the variable for perceived life stress was grouped into three categories: "not very to not at all stressful", "a bit", and "quite a bit to extremely stressful" to maintain a relatively equal number of cell frequencies across all categories. The reference category used for the logistic regression model was "a bit", to better understand the effects of low and high stress on outcomes of CD.

Total Household Income – All Sources

This was a derived variable in the CCHS to report the total household income amount using data linkage to tax records. The respondents were grouped into the following categories: No income or less than $20,000, $20,000 to $39,999, $40,000 to $59,999, $60,000 to $79,999, $80,000 or more, and not stated (0.1%). Those under "not stated" were subsequently deleted from the analysis, and household income was recoded into four categories: "$0- $59,999", "$60,000 to $99,999", "$100,000 to $149,999", and "$150K+". Since the median household income reported in Canada in 2015 was $70,336, the "$0-$59,999" category would represent lower income households (Statistics Canada, 2016a). The "$60,000 to $99,999" category was used as the reference variable to understand the effects of lower than median and higher than median income households on CD outcomes. Personal income was also used as a measure of SES in our analysis; however, household income provided better model diagnostics and thus was used as the final variable for reporting income in this study.

Highest Level of Education – Household

The household education variable was derived from the respondent's highest level of education. Due to an error in processing, the highest level of education for the respondent was represented by the first person in the household interviewed by Statistics Canada. Therefore, this variable is correct only for cases where the first respondent interviewed has the highest education in the household and may underestimate the highest level of education. Participants were categorized as either "less than secondary school graduation", "secondary school graduation, no post-secondary education", "post-secondary certificate diploma or university degree", and "not stated". Those who were categorized as "not stated" (4.5%) were removed from the analysis and household education was recoded into three categories: "below bachelors degree", "bachelors degree" and "above bachelors degree". Since more than half of Canadians (54%) report having either college or university degrees, we used “bachelors degree” as our reference category to better understand the effects of less than average and above average education on outcomes of CD.

Occupation Type

The exact categories of occupation types cannot be released in detail as a form of disclosure control, but the variable was recoded into four categories: “Management, Business, Health, Sciences, and Law”, “Sales, Service, Rec and Sport”, “Trades Agriculture, and Manufacturing”, or “Not working (Valid Skip)”. We wanted to compare outcomes of CD amongst those from different occupation types and those who were currently not working (valid skip) at the time of this survey (39.3%). Thus, “not working” was used at the reference category for our analysis.

Controls

Age

Age was a continuous variable in the CCHS but was recoded into categories with ages 20 to 39, 40 to 49, 50 to 54, 55 to 60, and 60 to 65 to better understand the association for working-age adults. For our research analysis, only working age participants were analysed to gauge more accurate statistical associations as CD outcomes may be insignificant below age 20 and over-represented after age 65. Model diagnostics also improved if only ages 20 to 65 were used instead of the continuous variable that included a much wider age range from ages 12 to over 100 years and older. Since the highest prevalence of CDs are in older adults, it was important to choose a reference category closer to this age group. We choose 50 to 54-year-olds as our reference group to better understand the association of CDs amongst those under 50-years-old, and above 55.

Sex/Gender

Due to a higher prevalence of both heart disease and diabetes in males, we choose females—who made up 50.7% of the sample—as our reference group. This way, we had a larger sample of those reporting a diagnosis.

Cultural/ Racial Background

The survey was predominately answered by those whose cultural or racial background is considered to be "White" (71.6%). Every other minority race or cultural background was recoded as "other" to form a binary variable. Those who were grouped as "valid skip" (3.7%) or "not stated" (3.9%) were removed from the analysis. To understand the effect of CDs in minority populations, we choose the "White only" category as our reference group.

BMI

The only continuous variable added in our logistic regression model was an adjusted measure of BMI. This was a derived variable adjusted using age, sex, self-reported BMI, and pregnant status. Both BMI and waist circumference are highly correlated to outcomes of heart disease and diabetes (Bays, Chapman, Grandy, & Group, 2007; Flint et al., 2010). As such, it was important to include BMI in our regression model to account for any confounding based on the weight and fat distribution of the individual.

Fruit and Vegetable Intake

Daily consumption of fruits and vegetables was an important variable to include in our analysis as an indicator of overall diet quality. However, it is important to note that it is very difficult to measure average diet quality due to limitations presented by the cross-sectional nature of this survey. In addition, diet is a sensitive subject for many, and respondents can be more inclined to recall incorrectly. Researchers in America showed that self-reported measures on a Food Frequency Questionnaire explained <10% of actual energy intake (Dhurandhar et al., 2015). The variable measured by the CCHS was derived from daily consumption of: pure fruit juice, fruit, dark green vegetables, potatoes, orange-coloured vegetables, and other vegetables. The continuous variable was recoded as a binary variable of "<5 fruits and vegetables per day" or ">/=5 fruits and vegetables per day", with the latter serving as the referencing category.

Type of Smoker

Cigarette smoking is a well-known risk factor for both heart disease and type II diabetes (Chang, 2012; Control & Prevention, 2010). Due to the higher prevalence of CDs amongst those who smoke chronically, it was important to control for smoking status as a confounding factor in our analysis. The type of smoker was assessed by the following question: "At the present time, do you smoke cigarettes every day, occasionally, or not at all?" Respondents answered either of the following: "Daily", "Occasionally", "Not at all", "Don't Know", or refused to answer. Due to the insignificant number of participants choosing either "don't know" or "refusal" (0.1%), these categories were removed from our analysis and the variable was recoded into binary categories or either "daily or occasionally" or "not at all". No smoking was chosen as the reference category to better understand the effect smoking behaviour can have to CD outcomes.

Alcohol Drinking Status

Binge drinking is also shown to increase the risk of developing type II diabetes and heart disease through impairing hypothalamic signalling (Lindtner et al., 2013; Mukamal & Rimm, 2001). Controlling for drinking status was important in understanding the true association between SES, chronic stress, and CD outcomes. Due to higher missingness in the "frequency of drinks" variable, we used the "type of drinker in the past 12 months" variable reported by the CCHS instead. This variable was derived from the following: had a drink in lifetime, drank alcohol in the last 12 months, and drinking frequency in the past 12 months. The categories consisted of “Regular drinker”, “Occasional drinker”, or “Did not drink in the last 12 months”, and 0.5% of respondents who were categorized as “Not stated” were removed from our analysis. To understand the effects of drinking on CD outcomes, “no drinking in the last 12 months” was the reference category for our analysis.

Physical Activity Status

The last behaviour risk factor we controlled for in our analysis was an indicator of physical activity status, which is highly correlated with outcomes of both chronic diseases (Ford & Caspersen, 2012; Hamilton, Hamilton, & Zderic, 2014; Joseph et al., 2016). The physical activity indicator was derived from the age and total minutes of moderate to vigorous activity per week, and grouped into either: “active”, “moderately active”, “somewhat active”, “sedentary” or “valid skip”, with 1.7% categorized as “not stated”. All categories were used for our analysis except for “valid skip” or “not stated”, which were removed from the regression analyses.

3.4. Multivariate Analyses

Research Question 1a

To answer our first research question, we used multivariate logistic regression analyses to model an association between CD status and non-traditional risk factors as the predictor variables. The main outcome variables of the study were self-reported chronic disease outcomes of heart disease and diabetes (**Equation I**). Although there is a variable to distinguish between type I and type II diabetes, the significantly larger prevalence of type II diabetes (approximately 90%) allows us to simply use those who answered yes to having diabetes (Public Health Agency of Canada, 2017a). Due to the binary nature of the response variables (either disease is present or absent), a binary logistic regression model was the most appropriate statistical technique to answer our first research objective. The main explanatory variables were self-reported stress at work (i) and socioeconomic status via household income (ii), occupational type (iii), and household education (iv). For question 1a, both disease models controlled for known confounders including age (v), sex (vi), and racial or cultural background (vii), and BMI (viii). Equation I was also repeated, replacing work stress with perceived life stress.

Equation I

(I) $$\eta_{i\,(CVD/T2D)} = \beta_0 + \beta_{1_i}WorkStress + \beta_{2_i}HouseholdIncome + \beta_{3_i}OccupationType + \beta_{4_i}HouseholdEducation + \beta_{5_i}Age + \beta_{6_i}Sex + \beta_{7_i}Race/Cul + \beta_{8_i}BMI$$

Research Question 1b

Further analysis was performed to answer the second part of our first research objective by controlling for the traditional behaviour risk factors, including fruit and vegetable intake (ix), smoking status (x), sedentary behaviour in previous three months (xi), and drinking behaviour (xii). The association between the predictor variables and CD outcomes will be reported in odds ratios and significance will be determined at $p < 0.05$ (**Equation II**). Equation II was also reproduced for perceived life stress, by replacing work stress.

Equation II

$$\text{(II)} \quad \eta_{i(CVD/T2D)} = \beta_0 + \beta_{1i}WorkStress + \beta_{2i}HouseholdIncome + \beta_{3i}OccupationType + \beta_{4i}HouseholdEducation + \beta_{5i}Age + \beta_{6i}Sex + \beta_{7i}Race/Cul + \beta_{8i}BMI + \beta_{9i}FruitVeg\ Intake + \beta_{10i}Smoking\ Status + \beta_{11i}Physical\ Inactivity + \beta_{12i}Drinking\ Status$$

Research Question 2

As informed by our literature review, the exact mechanism(s) involved in how workplace stress and SES act together on CD outcomes is understudied in Canada. Thus, to effectively answer our second research objective, we wanted to understand the joint effects of workplace stress and SES on cardiovascular disease and type II diabetes in our models. We can understand the joint effects by calculating the interaction of these terms. Many epidemiological researchers add an interaction term (workplace stress*socioeconomic status) to the logistic regression model to determine if there is a significant interaction effect between the two factors. However, adding the product term in the regression model—or multiplicative interaction—does not assure the absence of evidence of interaction between the two factors, only that data appear to conform to multiplicativity of effects (Richardson, 2009). Therefore, the research study also assessed the joint effects of the two non-traditional risk factors using interaction on an additive scale. This type of interaction measure is also known as the relative excess risk due to interaction (RERI) (VanderWeele, 2015). If the RERI > 0, this will indicate a positive additive interaction, whereas a RERI < 0 will indicate a negative additive interaction (Knol, 2011). The RERI between self-reported perceived life stress and each aspect of SES was determined for each chronic disease outcome to understand if additive joint effects exist in Canada.

Chapter 4.0 Results

4.1 Sample Characteristics

A total of 78,023 respondents (weighted n=21,700,505) from the ages of 20 to 65 were included in the data analysis, with a mean age of 47 for the sample included (Table 1). Approximately 51% of the total sample was female and 49% was male. A majority of participants (73%) in the CCHS are culturally or racially described as white and all other race and ethnicities (27%) were categorized as "other". Additionally, 24% of the population reported completing a bachelor's degree, whereas only 19% of the population had a high school education or less. Roughly 7% of the participants had reported being diagnosed with diabetes and 5% of the participants had reported being diagnosed with heart disease. The household income distribution was categorized into $0-$59,999, $60K-$99,999, $100K-$149,999, and $150K and above, with approximately 49% of individuals with self-reported diabetes and 52% individuals with self-reported heart disease falling below the median Canadian household income and reference category of $60K-$99,999. 51% of individuals with self-reported diabetes and 48% individuals with self-reported heart disease had a household income of $60,000 or above. In terms of occupation group, 39% of respondents were not considered to be working full-time at the time of data collection and were grouped under "valid skip" in the survey. This group was added to our analysis to capture individuals who might have been unemployed at the time of data collection.

Approximately 18% of the population was inactive or sedentary, and 66% ate less than five servings of fruits and vegetables on most days. Type of drinker was used instead of number of alcoholic drinks per week to gain a better understanding of the average amount of alcohol consumed by the respondent. 60% of study participants were categorized as "regular drinkers" with approximately 24% reporting not having a drink in the last 12 months. Likewise, type of smoker was used to understand average smoking behaviour of the sample. 83% reported smoking not at all when asked if "at the present time, do you smoke cigarettes every day?"

Table 1: Sample Characteristics and Bivariate Associations between Independent variables and Diabetes and Heart Disease Outcomes (2015-2016)

	Diabetes Outcome		Heart Disease Outcome	
Variables	**Total *n* = 78, 023* (% of total population) Has disease = 5,449 (6.98%)**	**P-value**	**Total *n* = 78, 023* (% of total population) Has disease = 3,496 (4.48%)**	**P-value**
Sex	**5,449 (100%)**	**<0.0001**	**3,496 (100%)**	**<0.0001**
Male	3,113 (57.1%)		2,028 (58.01%)	
Female	2,336 (42.9%)		1,468 (41.99%)	
Age	**3,127 (57.39%)**	**<0.0001**	**1,660 (47.48%)**	**<0.0001**
20-39 Years Old	317 (10.14%)		144 (8.68%)	
40-49 Years Old	619 (19.80%)		222 (13.37%)	
50-54 Years Old	550 (17.59%)		219 (13.19%)	
55-59 Years Old	719 (22.99%)		426 (25.66%)	
60-65 Years Old	922 (29.48%)		649 (39.10%)	
Race or Cultural Origin	**5,449 (100%)**	**0.0812**	**3,496 (100%)**	**<0.0001**
White	4,269 (78.34%)		3,109 (88.93%)	
Other	1,180 (21.66%)		386 (11.04%)	
Household Income	**5,449 (100%)**	**<0.0001**	**3,496 (100%)**	**<0.0001**
$0-$59,999	2,669 (48.98%)		1,828 (52.29%)	
$60K-$99,999	1,425 (26.15%)		794 (22.71%)	
$100K-$149,999	771 (14.14%)		470 (13.44%)	
$150K+	585 (10.73%)		404 (11.56%)	
Household Education	**5,170 (94.88%)**	**<0.0001**	**3,326 (95.14%)**	**<0.0001**
Below Bachelors Degree	3,750 (72.53%)		2,418 (72.70%)	
Bachelors Degree	897 (17.35%)		508 (15.27%)	
Above Bachelors Degree	523 (10.12%)		400 (12.03%)	
Occupation Level	**5,449 (100%)**	**<0.0001**	**3,496 (100%)**	**<0.0001**
Management, Business, Health, Sciences, and Law	1,175 (21.56%)		621 (17.76%)	
Sales, Service, Rec and Sport	592 (10.86%)		284 (8.12%)	
Trades, Agriculture, and Manufacturing	548 (10.06%)		258 (7.38%)	
Not Working (Valid Skip)	3,134 (57.52%)		2,332 (66.70%)	
Stress at Work	**5,449 (100%)**	**<0.0001**	**3,496 (100%)**	**<0.0001**
Not very to Not at all	814 (14.94%)		414 (11.84%)	
A bit	1,131 (20.76%)		545 (15.59%)	
Quite a bit/Extremely	684 (12.55%)		411 (11.76%)	
Not Stated	2,820 (51.75%)		2,126 (60.81%)	

Table 1 [Continued]: Sample Characteristics and Bivariate Associations between Independent variables and Diabetes and Heart Disease Outcomes (2015-2016)

	Diabetes Outcome		Heart Disease Outcome	
Variables	**Total *n* = 78, 023* (% of total population) Has disease = 5,449 (6.98%)**	**P-value**	**Total *n* = 78, 023* (% of total population) Has disease = 3,496 (4.48%)**	**P-value**
Perceived Life Stress	**5,449 (100%)**	**<0.0001**	**3,496 (100%)**	**<0.0001**
Not very to Not at all	2,243 (41.16%)		1,481 (42.36%)	
A bit	2,130 (39.09%)		1,227 (35.10%)	
Quite a bit/Extremely	1,076 (19.75%)		788 (22.54%)	
Fruit and Vegetable Intake	**5,449 (100%)**	**<0.0001**	**3.496 (100%)**	**<0.0001**
<5 Per day	4,013 (73.65%)		2,533 (73.03%)	
≥ 5Per Day	1,436 (26.35%)		963 (27.55%)	
Smoking Status	**5,449 (100%)**	**0.0027**	**3,496 (100%)**	**0.3974**
Daily or Occasional	895 (16.43%)		608 (17.39%)	
Not at all	4,554 (83.57%)		2,888 (82.61%)	
Drinking Status	**5,449 (100%)**	**<0.0001**	**3,496 (100%)**	**<0.0001**
Regular Drinker	2,548 (46.76%)		1,922 (54.98%)	
Occasional Drinker	1,238 (22.72%)		643 (18.39%)	
Did not drink in last 12 months	1,663 (30.52%)		931 (26.63%)	
Physical Activity Status	**5,375 (98.64%)**	**<0.0001**	**3,459 (98.94%)**	**<0.0001**
Active	2,306 (42.90%)		1,551 (44.84%)	
Moderately Active	573 (10.66%)		398 (11.51%)	
Somewhat Active	753 (14.01%)		465 (13.44%)	
Sedentary	1,743 (32.43%)		1,045 (30.21%)	

*Note: weighted and bootstrapped estimates shown

4.2 Associations between Non-traditional Risk Factors and CD Outcomes, controlling for Age, Sex, Race/Cultural Background, BMI

Simple models of SES, perceived stress at work, and perceived life stress on CD outcomes

Three logistic regression models were estimated to understand the population-level association between: one, measures of socioeconomic status (household income, household education, occupation level); two, self-reported stress levels at work; and three, self-reported perceived life stress on both chronic disease outcomes. Bootstrapped weights were used to improve the precision of the reported confidence intervals. To answer our first research question, each model only adjusted for age, sex, race/cultural background, and BMI.

Socioeconomic Status

Diabetes: Logistic regression analysis showed a significant association between self-reported diabetes and overall levels of SES (household income, household education, occupation level) when controlling for age, sex, race/cultural background, and BMI (Table 2). Households with an annual income of $150,000 showed almost half the odds of having diabetes than those with the median household income, $60,000 to $99,999 ($p<0.0001$). Persons with less than a bachelor's degree had approximately 30% higher odds of reporting a diabetes outcome than those who had a bachelor's degree ($p=0.0005$). All occupation types had 30% lower odds of reporting a diabetes outcome than those who were thought to be unemployed at the time of survey data collection ($p=0.002$).

Heart Disease: Logistic regression analysis showed a significant association between self-reported heart disease and overall levels of SES (household income, household education, occupation level) when controlling for age, sex, race/cultural background, and BMI (Table 2). Households with an annual income below the median in Canada ($0 to $59,999) showed 40% higher odds of having heart disease than the household income range of $60,000 to $99,999 ($p=0.0005$). Persons with less than a bachelor's degree had approximately 44% higher odds of reporting heart disease than those who had a bachelor's degree (p=0.0005). Similar to diabetes outcome, all types of occupations had significantly lower odds of reporting heart disease than those who were considered unemployed at the time of survey data collection (p <0.0001).

Self-reported stress levels

Diabetes: Logistic regression models showed a significant association between self-reported diabetes outcome and both self-perceived stress levels at work and perceived life stress when controlling for age, sex, race/cultural background, and BMI (Table 2). Ironically, those who did not answer the workplace stress question ("not stated") had the highest odds of reporting outcomes of diabetes. This could be because those who are highly stressed at work feel uncomfortable sharing this information with their employer (Howatt, 2017). The odds of this group reporting a diabetes outcome was almost 50% higher (p<0.0001) than those who reported not being very stressed at work or being extremely stressed at work. On the other hand, those who reported perceived life stress as not very or not at all stressed had 18% lower odds of reporting a diabetes outcome.

Heart Disease: The logistic regression models showed a significant association between self-reported heart disease outcome and both self-perceived stress levels at work and perceived life stress when controlling for age, sex, race/cultural background, and BMI (Table 2). Those who did not answer the workplace stress question had an even higher odds of reporting outcomes of heart disease than diabetes. This group categorized as "not stated" reported 74% higher odds of having heart disease than those who reported having "a bit" of workplace stress (p<0.0001). As predicted, those who reported having "quite a bit" or "extremely" high levels of life stress had almost 58% higher odds of reporting heart disease (p<0.0001). Those who reported being "not very" or "not at all" stressed in life had 20% lower odds of reporting heart disease (p=0.02).

Table 2: Simple models of non-traditional risk factors and CD outcomes controlling for age, sex, race/cultural background, and BMI

	Diabetes Outcome			Heart Disease Outcome		
Non-Traditional Risk Factors	**OR**	**95% C.I.**	**P-value**	**OR**	**95% C.I.**	**P-value**
Household Income*						
$0-$59,999 vs $60K - $99,999	1.113	[0.916, 1.353]	0.2820	**1.416**	**[1.165, 1.721]**	**0.0005**
$100K-$149,999 vs $60K - $99,999	0.869	[0.704, 1.073]	0.1909	0.965	[0.752, 1.237]	0.7773
$150,000+ vs $60K - $99,999	**0.669**	**[0.552, 0.811]**	**<0.0001**	0.919	[0.713, 1.183]	0.5113
Household Education*						
Above Bachelors Degree vs Bachelors Degree	0.925	[0.728, 1.175]	0.5217	1.256	[0.935, 1.688]	0.1302
Below Bachelors Degree vs Bachelors Degree	**1.326**	**[1.130, 1.556]**	**0.0005**	**1.444**	**[1.106, 1.886]**	**0.0070**
Occupation Level*						
Management, Business, Health, Science and Law vs. Not Working	**0.705**	**[0.595, 0.837]**	**<0.0001**	**0.729**	**[0.578, 0.920]**	**0.0077**
Sales, Service, Rec and Sport vs. Not Working	**0.735**	**[0.607, 0.890]**	**0.0016**	**0.663**	**[0.508, 0.866]**	**0.0026**
Trades, Agriculture, and Manufacturing vs. Not Working	**0.701**	**[0.578, 0.851]**	**0.0003**	**0.626**	**[0.480, 0.817]**	**0.0006**
Self-perceived Stress at Work**						
Not Stated vs. A bit	**1.522**	**[1.274, 1.819]**	**<0.0001**	**1.743**	**[1.325, 2.294]**	**<0.0001**
Not very/Not at all vs. A bit	0.966	[0.776, 1.203]	0.7556	0.935	[0.756, 1.157]	0.5383
Quite a bit/Extremely vs. A bit	0.925	[0.736, 1.163]	0.5061	1.180	[0.918, 1.516]	0.1965
Perceived Life Stress***						
Not very/Not at all vs. A bit	**0.824**	**[0.713, 0.952]**	**0.0087**	**0.806**	**[0.668, 0.972]**	**0.0241**
Quite a bit/Extremely vs. A bit	1.603	[0.821, 1.376]	0.6445	**1.585**	**[1.312, 1.916]**	**<0.0001**

Total n = 78,023 (weighted and bootstrapped sample shown only)

*Model 1 (SES) Diabetes| Heart Disease: -2 Log L = 20,130.86 | 12,770.41, AIC = 20,162.86 | 12,802.41, c-statistic = 0.80 | 0.78

**Model 2 (Work Stress) Diabetes| HD: -2 Log L = 21,252.90 |13,487.79, AIC = 21,274.90 | 13,509.79, c-statistic= 0.80 | 0.78

***Model 3 (Life Stress) Diabetes| HD: -2 Log L = 21,319.45 | 13,467.67, AIC = 21,339.45 | 13,487.67, c-statistic = 0.79 | 0.77

Multivariable Models of SES and perceived stress at work or perceived life stress on CD outcomes

We then added both variables for all aspects of SES and self-reported stress levels to our logistic regression models while controlling for sex, age, race/cultural background, and BMI (Table 3). Two separate logistic regression models were analyzed to understand the true population-level association between self-reported perceived stress levels at work and all aspects of SES on heart disease and diabetes status. Bootstrapped weights were used to improve the precision of the reported confidence intervals.

Self-Perceived Stress at Work and SES

Diabetes: When both self-reported stress at work and all aspects of SES were added to the model, occupation type and perceived stress at work were no longer significantly associated to self-reported outcomes of diabetes (Table 3). This may be due to either variable mediating the association between the outcome and thus, leading to attenuating the association between the workplace variable and diabetes outcome. Those with a household income of $150,000 or above still showed almost 30% lower odds of reporting diabetes than $60,000 to $99,999 ($p < 0.0001$). As well, those with less than a bachelor's degree showed a 33% higher odds of reporting diabetes than those with a bachelor's degree ($p=0.0006$).

Heart Disease: Occupation type no longer remained significantly associated to outcomes of heart disease when both self-reported stress at work and all aspects of SES were added to the model (Table 3). We report the ORs for the other variables after removing occupation type from the model through backward selection. Those who did not state self-perceived stress levels at work had 39% higher odds of reporting heart disease than those reporting a bit of stress at work ($p=0.011$). Having a household income below the median at $0 to $59,999 shows 40% higher odds of reporting heart disease than $60,000 to $99,999 ($p=0.0007$). As well, those with less than a bachelor's degree showed a 40% higher odds of reporting heart disease than those with a bachelor's degree (p=0.0044).

Table 3: Multivariable models of self-perceived stress at work, SES, and chronic disease outcomes controlling for age, sex, race/cultural background, and BMI

	Diabetes Outcome			Heart Disease Outcome		
Non-Traditional Risk Factors	**OR**	**95% C.I.**	**P-value**	**OR**	**95% C.I.**	**P-value**
Self-perceived Stress at Work						
Not Stated vs. A bit	**1.413**	**[1.194, 1.671]**	**<0.0001**	**1.472**	**[1.094, 1.980]**	**0.0106**
Not very/Not at all vs. A bit	0.949	[0.738, 1.219]	0.6803	0.851	[0.680, 1.064]	0.1556
Quite a bit/Extremely vs. A bit	0.955	[0.739, 1.234]	0.7242	1.182	[0.903, 1.547]	0.2228
Household Income						
$0-$59,999 vs $60K - $99,999	1.114	[0.923, 1.343]	0.2603	**1.422**	**[1.162, 1.741]**	**0.0007**
$100K-$149,999 vs $60K - $99,999	0.871	[0.702, 1.079]	0.2063	0.963	[0.749, 1.239]	0.7707
$150,000+ vs $60K - $99,999	**0.672**	**[0.554, 0.815]**	**<0.0001**	0.919	[0.708, 1.191]	0.5215
Household Education						
Above Bachelors Degree vs Bachelors Degree	0.924	[0.727, 1.176]	0.5213	1.262	[0.936, 1.701]	0.1272
Below Bachelors Degree vs Bachelors Degree	**1.331**	**[1.136, 1.559]**	**0.0004**	**1.435**	**[1.119, 1.839]**	**0.0044**
Occupation Level						
Management, Business, Health, Science and Law vs. Not Working	0.825	[0.616, 1.104]	0.1943	0.823	[0.617, 1.098]	0.1853
Sales, Service, Rec and Sport vs. Not Working	0.862	[0.661, 1.124]	0.2734	0.772	[0.545, 1.093]	0.1449
Trades, Agriculture, and Manufacturing vs. Not Working	0.821	[0.625, 1.077]	0.1544	0.728	[0.441, 1.201]	0.2139

Total n = 78,023 (weighted and bootstrapped sample shown only)

*Full Model (Diabetes): -2 Log L = 20,127.50, AIC = 20,159.50, c-statistic = 0.79
*Full Model (Heart Disease): -2 Log L = 12,761.05, AIC = 12,793.05, c-statistic = 0.78

Self-Perceived Life Stress and SES

Diabetes: When we added both self-reported life stress and all aspects of SES, our results differed drastically compared to those with workplace stress levels (Table 4). As predicted, since there is likely less mediation between life stress and occupation level, both were now found to be significantly associated to outcomes of diabetes. Reporting low levels of life stress (not very/not at all) showed 23% lower odds of reporting outcomes of diabetes (p=0.0005). Having a household income of $150,000 or above showed 36% lower odds of reporting diabetes than $60,000 to $99,999 (p <0.0001). As well, results found that those with less than a bachelor's degree report significantly higher odds (33%) of reporting diabetes than those with a bachelor's degree (p=0.0005). All occupation types were now significantly associated to outcomes of diabetes and these odds were lower compared to persons who were maybe not working at the time of the survey (p=0.0006).

Heart Disease: When both self-reported life stress and all aspects of SES were added to the model, we again found that perceived life stress and occupation type remained significantly associated to heart disease outcome (Table 4)**.** Reporting low levels of life stress (not very/not at all) showed 28% lower odds of reporting outcomes of heart disease (p=0.0023). Whereas those who reported "no household income or below $59, 999" showed 36% higher odds of reporting heart disease (p=0.0023), than those who had a household income between $60,000 to $99, 999. As well, those who reported less than a bachelor's degree showed 44% higher odds of reporting heart disease than those with a bachelor's degree (p=0.0081). All occupation types were significantly associated to heart disease outcome, with much lower odds of reporting disease outcome than those who were not working at the time (p=0.0005).

Table 4: Multivariable models of perceived life stress, SES, and chronic disease outcomes controlling for age, sex, race/cultural background, and BMI

	Diabetes Outcome			Heart Disease Outcome		
Non-Traditional Risk Factors	**OR**	**95% C.I.**	**P-value**	**OR**	**95% C.I.**	**P-value**
Self-perceived Life Stress						
Not very/Not at all vs. A bit	**0.771**	**[0.666, 0.893]**	**0.0005**	**0.723**	**[0.593, 0.882]**	**0.0023**
Quite a bit/Extremely vs. A bit	1.067	[0.820, 1.389]	0.6279	1.538	[1.242, 1.904]	0.6982
Household Income						
$0-$59,999 vs $60K - $99,999	1.097	[0.906, 1.329]	0.3414	**1.364**	**[1.118, 1.664]**	**0.0023**
$100K-$149,999 vs $60K - $99,999	0.863	[0.698, 1.067]	1.1732	0.952	[0.743, 1.220]	0.6982
$150,000+ vs $60K - $99,999	**0.664**	**[0.548, 0.804]**	**<0.0001**	0.902	[0.698, 1.164]	0.4260
Household Education						
Above Bachelors Degree vs Bachelors Degree	0.922	[0.727, 1.170]	0.5051	1.230	[0.915, 1.653]	0.1695
Below Bachelors Degree vs Bachelors Degree	**1.329**	**[1.133, 1.558]**	**0.0005**	**1.438**	**[1.099, 1.881]**	**0.0081**
Occupation Level						
Management, Business, Health, Science and Law vs. Not Working	**0.670**	**[0.567, 0.791]**	**<0.0001**	**0.647**	**[0.508, 0.824]**	**0.0004**
Sales, Service, Rec and Sport vs. Not Working	**0.712**	**[0.587, 0.864]**	**0.0006**	**0.620**	**[0.475, 0.809]**	**0.0005**
Trades, Agriculture, and Manufacturing vs. Not Working	**0.686**	**[0.565, 0.834]**	**0.0002**	**0.597**	**[0.457, 0.780]**	**0.0002**

Total n = 78,023 (weighted and bootstrapped sample shown only)

*Full Model (Diabetes): -2 Log L = 20,086.40, AIC = 20,122.40, c-statistic = 0.80

*Full Model (Heart Disease): -2 Log L = 12,653.99, AIC = 12,689.99, c-statistic = 0.79

4.3 Associations between Non-traditional Risk Factors and CD Outcomes, controlling for Additional Behaviour Risk Factors

For research question 1b, additional controls were added to the logistic regression models in an effort to gauge the true association between non-traditional risk factors and CD outcomes. If the traditional disease risk factors—physical activity status, fruit and vegetable intake, smoking status, and alcohol intake—have a stronger association to outcomes of heart disease and diabetes, then we should see an attenuation of the associations between SES and perceived stress levels on outcomes of CDs. Bootstrapped weights were used to improve the precision of the reported confidence intervals.

Separate models of Behaviour Risk Factors and CD outcomes, controlling for age, sex, race, and BMI

Diabetes: As predicted, most measures of behaviour risk factors were significantly associated to outcomes of self-reported diabetes except for fruit and vegetable intake (Table 5). This may be due to the difficulty of capturing a healthy diet on a survey (Dhurandhar et al., 2015). Respondents could be eating more than 5 servings of fruits and vegetables but also consume fast food and calorie dense foods. Thus, due to several longitudinal studies showing a significant association between a healthy diet and lower outcomes of heart disease and diabetes, we are going to assume the variable did not adequately represent consumption of a healthy diet. Those who smoked daily or occasionally showed 30% higher odds of reporting diabetes outcome than those who did not smoke ($p=0.0035$). As well, persons who reported being active most days of the week had significantly lower odds (24%) of reporting diabetes than those who were somewhat active ($p=0.0143$). Surprisingly, those who drank alcohol regularly had an almost 50% lower odds of reporting diabetes than those who did not drink in the last 12 months ($p<0.0001$). However, it is important to note that due to the cross-sectional nature of the data, this could be due to several confounding factors we did not account for in our analysis. For example, those who reported drinking alcohol could potentially have larger social groups and good social connections are associated to better physical health (Cockerham, Hamby, & Oates, 2017).

Heart Disease: The only variables of behaviour risk factors that were significantly associated to outcomes of self-reported heart disease were smoking status and alcohol status (Table 5). Only one level of physical activity showed a significant association to having heart disease, and thus the overall variable was not found significant. Smoking status showed significantly higher odds of reporting heart disease than diabetes, with those who smoked daily or occasionally having 55% higher odds of heart disease than those who did not smoke ($p<0.0001$). As well, persons who reported being active most days of the week had an equally significantly lower odds of reporting heart disease as those with diabetes—around 30% less than those who were somewhat active ($p=0.0322$). Surprisingly, those who drank alcohol on a regular basis again showed significantly lower odds of having heart disease than those who did not drink in the last 12 months ($p=0.0022$). However, recent studies are finding that alcohol may play a key role in exacerbating other chronic diseases, such as cancer; and thus, this association should not be considered causal (Shield, Soerjomataram, & Rehm, 2016).

Table 5: Behaviour risk factors and CD outcomes controlling for age, sex, race/cultural background, and BMI

	Diabetes Outcome			Heart Disease Outcome		
Behaviour Risk Factors	**OR**	**95% C.I.**	**P-value**	**OR**	**95% C.I.**	**P-value**
Smoking Status						
Daily or Occasional vs. Not at all	**1.296**	**[1.089, 1.541]**	**0.0035**	**1.558**	**[1.248, 1.946]**	**<0.0001**
Physical Activity Status						
Active vs. Somewhat Active	**0.762**	**[0.613, 0.947]**	**0.0143**	**0.728**	**[0.544, 0.973]**	**0.0322**
Moderately Active vs. Somewhat Active	0.753	[0.560, 1.013]	0.0605	0.946	[0.652, 1.373]	0.7718
Sedentary vs. Somewhat Active	1.234	[0.939, 1.623]	0.1313	0.957	[0.722, 1.269]	0.7610
Fruit & Vegetable Intake						
<5 Servings per day vs. ≥ 5 servings per day	1.088	[0.922, 1.284]	0.3179	1.018	[0.807, 1.285]	0.8781
Alcohol Drinking Status						
Occasional Drinker vs. Did not drink in the last12 months	1.067	[0.811, 1.405]	0.6429	0.981	[0.691, 1.391]	0.9133
Regular Drinker vs. Did not drink in the last 12 months	**0.515**	**[0.429, 0.618]**	**<0.0001**	**0.703**	**[0.562, 0.881]**	**0.0022**

Total n = 78,023 (weighted and bootstrapped sample shown only)

*Full Model (Diabetes): -2 Log L = 20,692.99, AIC = 20,722.99, c-statistic = 0.80

*Full Model (Heart Disease): -2 Log L = 13,339.20, AIC = 13,369.20, c-statistic = 0.77

Combined models of Behaviour Risk Factors and Non-traditional Risk Factors on CD outcomes

Self-perceived stress at work

Diabetes: Table 6 shows the results of our combined model with behaviour risk factors serving as additional controls in our association between SES, self-perceived stress at work, and diabetes outcome. Our results were similar to those from our previous models when both occupation type and workplace stress were added together, neither variable was significantly associated to diabetes outcome. After removing occupation type from our model through step-wise backward selection, self-reported stress at work was found significantly associated to diabetes outcome. As well, smoking status was no longer significantly associated to diabetes outcome once socioeconomic factors and stress levels were added to the model. Even after controlling for traditional disease risk factors, a household income of $150,000 or above showed an almost 30% lower odds of reporting diabetes than those with an income between $60K to $99,999 (p=0.0010). Those who had less than a bachelors degree showed 24% higher odds of diabetes than those with a bachelors degree (p=0.0114). If socioeconomic and stress factors are found significantly associated to diabetes outcome even after adjusting for behaviour risk factors, then we need to learn the exact mechanisms involved in creating disparities in chronic disease outcomes aside from simply changing lifestyle behaviours.

Heart Disease: Results from our combined model of heart disease, SES, and self-perceived stress at work with behaviour risk factors serving as additional controls in addition to age, sex, race/cultural background and BMI, were similar to those for diabetes (Table 6). Both variables related to the workplace—occupational levels and self-perceived stress at work—were not found significantly associated to heart disease outcome when added together in the model. However, once we remove the occupational status variable, we again find that workplace stress becomes significantly associated to heart disease outcome (p=0.004). Smoking status also remined a significant factor in the outcome of heart disease, showing almost 47% higher odds of heart disease for those who smoked daily or occasionally versus those who did not smoke at all (p=0.0026). Even after controlling for traditional disease risk factors, no household income to $59,999 still showed almost 32% higher odds of reporting heart disease than those with an income between $60K to $99,999 (p=0.0074). Similar to diabetes, those with less than a bachelors degree reported 33% higher odds of heart disease than those with a bachelors degree (p=0.0291). We again found that socioeconomic and stress factors remained significantly associated to chronic disease outcome even after adjusting for behaviour risk factors. This supports findings that health disparities might exist even after changing lifestyle factors.

As well, because workplace stress was only significantly associated to chronic disease outcomes once we removed the variable for occupation level, there might be some mediation in the relationship between workplace stress, occupation type, and chronic disease outcome. Studies using longitudinal data can better investigate any mediation in the relationship between all these variables using mediation analysis.

Table 6: CD outcomes and Non-traditional Risk Factors (Work Stress and SES), Behaviour Risk Factors, and standard controls (age, sex, race/cultural background, BMI)

	Diabetes Outcome			Heart Disease Outcome		
Non-Traditional Risk Factors	**OR**	**95% C.I.**	**P-value**	**OR**	**95% C.I.**	**P-value**
Perceived Stress at Work						
Not Stated vs. A bit	1.096	[0.807, 1.488]	0.5585	**1.412**	**[1.055, 1.890]**	**0.0205**
Not very/Not at all vs. A bit	0.907	[0.709, 1.161]	0.4388	0.844	[0.676, 1.055]	0.1355
Quite a bit/Extremely vs. A bit	0.939	[0.720, 1.225]	0.6432	1.163	[0.885, 1.529]	0.2780
Household Income						
$0-$59,999 vs $60K - $99,999	1.006	[0.821, 1.234]	0.9526	**1.339**	**[1.093, 1.640]**	**0.0049**
$100K-$149,999 vs. $60K - $99,999	0.916	[0.732, 1.146]	0.4423	0.985	[0.763, 1.271]	0.9061
$150,000+ vs $60K - $99,999	**0.722**	**[0.595, 0.876]**	**0.0010**	0.951	[0.733, 1.235]	0.7070
Household Education						
Above Bachelors Degree vs Bachelors Degree	0.924	[0.721, 1.183]	0.5278	1.271	[0.943, 1.713]	0.1150
Below Bachelors Degree vs Bachelors Degree	**1.236**	**[1.049, 1.457]**	**0.0114**	**1.344**	**[1.053, 1.717]**	**0.0177**
Occupation Level						
Management, Business, Health, Science and Law vs. Not Working	0.837	[0.624, 1.124]	0.2373	0.828	[0.618, 1.109]	0.2055
Sales, Service, Rec and Sport vs. Not Working	0.827	[0.626, 1.092]	0.1806	0.751	[0.530, 1.065]	0.1084
Trades, Agriculture, & Manufacturing vs Not working	0.782	[0.593, 1.032]	0.0823	0.701	[0.417, 1.176]	0.1779
Behaviour Risk Factors						
Smoking Status						
Daily or Occasional vs. Not at all	1.222	[0.989, 1.510]	0.0631	**1.480**	**[1.168, 1.875]**	**0.0012**
Physical Activity Status						
Active vs. Somewhat Active	**0.765**	**[0.618, 0.947]**	**0.0138**	**0.725**	**[0.529, 0.992]**	**0.0445**
Moderately Active vs. Somewhat Active	0.714	[0.507, 1.005]	0.0536	0.901	[0.633, 1.281]	0.5602
Sedentary vs. Somewhat Active	1.234	[0.945, 1.612]	0.1221	0.938	[0.705, 1.246]	0.6566
Fruit & Vegetable Intake						
<5 Servings per day vs. ≥ 5 servings per day	1.042	[0.882, 1.231]	0.6294	1.004	[0.801, 1.259]	0.9712
Alcohol Drinking Status						
Occasional Drinker vs. Did not drink in the last12 months	1.097	[0.829, 1.450]	0.5173	1.033	[0.735, 1.453]	0.8500
Regular Drinker vs. Did not drink in the last 12 months	**0.551**	**[0.468, 0.648]**	**<0.0001**	**0.788**	**[0.639, 0.972]**	**0.0264**

Total n = 78,023 (weighted and bootstrapped sample shown only)

*Full Model (Diabetes): -2 Log L = 19,586.59, AIC = 19,638.59, c-statistic = 0.81

*Full Model (Heart Disease): -2 Log L = 12,701.31, AIC = 12,739.31, c-statistic = 0.78

Self-perceived life stress

Diabetes: Table 7 details surprisingly different results than our previous model of self-reported stress at work. Here, perceived life stress was used instead as an indicator of stress levels, along with each variable of SES, and behaviour risk factors, age, sex, race/cultural background, and BMI served as controls. We found that both occupation type and perceived life stress remained significantly associated to outcomes of diabetes even when traditional disease risk factors were added to our model. All types of occupations showed significantly lower (~30%) odds of reporting diabetes than those who might have been unemployed at the time (p=0.0012). Similar to our results from workplace stress, a household income of $150,000 or above still showed almost 30% lower odds of reporting diabetes than those with an income between $60K to $99,999 (p=0.0007). As well, those with less than a bachelor's degree reported 24% higher odds of diabetes than those with a bachelors degree (p=0.0095). We again found that both self-reported life stress and socioeconomic factors remained significantly associated to outcomes of diabetes even after controlling for disease risk factors. Thus, socioeconomic factors and stress levels might have an independent association to diabetes outcome.

Heart Disease: Results from our combined model of self-perceived life stress controlling for behaviour risk factors found similar results to those for diabetes, both self-reported life stress levels and occupation type remained significantly associated to heart disease outcome (Table 7). Both drinking status and fruit and vegetable intake were not found significantly associated to heart disease outcome once stress and SES were added to the model. Smoking status and physical activity levels remined significant factors in predicting self-reported outcomes of heart disease. Even after controlling for traditional disease risk factors, no household income to $59,999 showed around 30% higher odds of heart disease than those with an income between $60K to $99,999 (p=0.0141). Similar to diabetes, those with less than a bachelor's degree reported 33% higher odds of heart disease than those with a bachelor's degree. We found that all types of occupations reported significantly lower odds (~30-40%) of having heart disease than those who were not working at the time of this survey (p=0.0012). Those who reported "not very or not at all" to having life stress most days of the week had significantly lower odds (~26%) of reporting heart disease than those who reported having "a bit" of life stress (p=0.0031). On the other hand, those who reported being "quite a bit" or "extremely" stressed on most days had 48% higher odds of heart disease outcome than those who reported "a bit" of life stress (p=0.0006).

Since both self-perceived stress levels and all aspects of socioeconomic factors remained significantly associated to outcomes of heart disease in the presence of behaviour risk factors, this indicates that both variables might be independently associated to disease outcome. Models with self-perceived life stress showed different results for occupation level than self-perceived stress at work possibly due to occupation type mediating the relationship between workplace stress and outcomes of diabetes and heart disease.

Table 7: CD outcomes and Non-traditional Risk Factors (Life Stress and SES), Behaviour Risk Factors, and standard controls (age, sex, race/cultural background, BMI)

	Diabetes Outcome			Heart Disease Outcome		
Non-Traditional Risk Factors	**OR**	**95% C.I.**	**P-value**	**OR**	**95% C.I.**	**P-value**
Perceived Life Stress						
Not very/Not at all vs. A bit	**0.791**	**[0.684, 0.916]**	**0.0017**	**0.741**	**[0.607, 0.903]**	**0.0031**
Quite a bit/Extremely vs. A bit	1.035	[0.791, 1.355]	0.8014	**1.481**	**[1.183, 1.853]**	**0.0006**
Household Income						
$0-$59,999 vs $60K - $99,999	1.001	[0.818, 1.225]	0.9935	**1.285**	**[1.052, 1.569]**	**0.0141**
$100K-$149,999 vs. $60K - $99,999	0.909	[0.729, 1.322]	0.3916	0.963	[0.747, 1.242]	0.7706
$150,000+ vs $60K - $99,999	**0.715**	**[0.589, 0.868]**	**0.0007**	0.942	[0.728, 1.220]	0.6515
Household Education						
Above Bachelors Degree vs Bachelors Degree	0.921	[0.721, 1.176]	0.5074	1.236	[0.921, 1.659]	0.1582
Below Bachelors Degree vs Bachelors Degree	**1.240**	**[1.054, 1.459]**	**0.0095**	**1.330**	**[1.024, 1.728]**	**0.0325**
Occupation Level						
Management, Business, Health, Science and Law vs. Not Working	**0.731**	**[0.620, 0.863]**	**0.0002**	**0.684**	**[0.533, 0.879]**	**0.0030**
Sales, Service, Rec and Sport vs. Not Working	**0.731**	**[0.605, 0.883]**	**0.0012**	**0.636**	**[0.484, 0.836]**	**0.0012**
Trades, Agriculture, & Manufacturing vs Not working	**0.697**	**[0.573, 0.848]**	**0.0003**	**0.604**	**[0.460, 0.794]**	**0.0003**
Behaviour Risk Factors						
Smoking Status						
Daily or Occasional vs. Not at all	1.202	[0.971, 1.488]	0.0918	**1.402**	**[1.093, 1.798]**	**0.0078**
Physical Activity Status						
Active vs. Somewhat Active	**0.766**	**[0.618, 0.949]**	**0.0148**	**0.729**	**[0.537, 0.990]**	**0.0430**
Moderately Active vs. Somewhat Active	**0.708**	**[0.502, 0.999]**	**0.0494**	0.889	[0.626, 1.263]	0.5109
Sedentary vs. Somewhat Active	1.232	[0.936, 1.620]	0.1360	0.928	[0.698, 1.234]	0.6069
Fruit & Vegetable Intake						
<5 Servings per day vs. ≥ 5 servings per day	1.037	[0.875, 1.228]	0.6747	0.999	[0.799, 1.249]	0.9926
Alcohol Drinking Status						
Occasional Drinker vs. Did not drink in the last12 months	1.097	[0.830, 1.448]	0.5158	1.031	[0.732, 1.452]	0.8630
Regular Drinker vs. Did not drink in the last 12 months	**0.551**	**[0.470, 0.646]**	**<0.0001**	0.818	[0.658, 1.018]	0.0717

Total n = 78,023 (weighted and bootstrapped sample shown only)

*Full Model (Diabetes): -2 Log L = 19,560.99, AIC = 19,610.99, c-statistic = 0.81

*Full Model (Heart Disease): -2 Log L = 12,493.41, AIC = 12,543.41, c-statistic = 0.79

4.4 Multiplicative and Additive Interaction

An interaction between two exposures exists if both are related in some way during a specific outcome (VanderWeele, 2015). Interactions help to shed light on the complexity of how certain outcomes come about since exposures rarely act in isolation to one another in the real world. Previous studies mainly focused on the interaction between genetic and environmental exposures, but two environmental exposures are known to interact as well (VanderWeele, 2015). Because the combined effect of exposures can differ from their individual effects, it was important to understand the effects of both stress levels and each level of socioeconomic status on outcomes of heart disease and diabetes in Canada. To do this, we consider both exposures separately in our model and then together through an interaction term. The contrast between the effects of both factors together versus each considered on its own is known as a measure of interaction on the **additive scale**. Interaction on an additive scale can show if the combined effects of two exposures is larger (or smaller) than the sum of the individual effects (Knol, 2011). On the other hand, **multiplicative interaction** is calculated when the effect of both exposures together exceeds the *product* of the effects of the exposures individually (VanderWeele, 2015). It is possible for an interaction to be present on one scale and absent on the other scale. This is why we reported both multiplicative and additive interaction for a complete understanding of the combined effects between perceived stress levels and socioeconomic status.

Additive interaction cannot be reported without relative risks which can only be obtained if the incidence of disease is measured (VanderWeele, 2015). Therefore, in order to use odds ratios in finding the interaction effects on an additive scale, we use a quantity called the “relative excess risk of interaction” (RERI). We estimated the additive interaction with covariate controls, using weighted bootstrapped logistic regression models and transformed the parameter estimates to obtain estimates of the relative excess risk due to interaction (RERI).

If the following model is fit to data:

$$\text{logit}\{P(Y=1) = \gamma_0 + \gamma_1 x_1 + \gamma_2 x_2 + \gamma_3 x_1 x_2 + \gamma_4 x_4$$

Then $RERI_{OR} = OR_{11} - OR_{10} - OR_{01} + 1$

$$= e^{\gamma 1 + \gamma 2 + \gamma 3} - e^{\gamma 1} - e^{\gamma 2} + 1$$

Thus, $RERI_{RR} = RR_{11} - RR_{10} - RR_{01} + 1 \approx RERI_{OR} = OR_{11} - OR_{10} - OR_{01} + 1$

This shows that we can estimate a measure of additive interaction, $RERI_{OR}$, using parameters from a logistic regression model that report odds ratios. It is important to note that this approach can only be used if the disease outcome is rare (VanderWeele, 2015). In our case, the prevalence of both diabetes and heart disease are <10%, so they are both considered rare diseases (Public Health Agency of Canada, 2017a, 2017b; VanderWeele, 2015). Fairly large sample sizes, such as those provided by the CCHS, are required to detect interaction and significance level. Thus, logistic regression models were used in our analysis to calculate more precise values of RERI.

Multiplicative Interaction

We will begin by elaborating on the results of including interaction terms in our logistic regression models. The variable for life stress was used to represent perceived chronic stress instead of workplace stress due to missing information on 30% of those who were not working at the time (valid skip). Six different models were created to include interaction terms; the first three models included the original variables of perceived life stress and SES included in our previous analysis (Table 8). The last three models used newly created variables with binary categories of only high levels of life stress and low levels of SES. Binary exposures might be more straightforward in fitting models testing for interactions (VanderWeele & Knol, 2014). Indeed, our model diagnostics showed lower values of Akaike information criterion (AIC) and slightly higher values of the concordance (c) statistic when the exposure was binary as opposed to categorical. Although the predictive ability of the c-statistic may be compromised when explanatory variables are not linear and normally distributed (Austin & Steyerberg, 2012).

Table 8: **Multiplicative Interaction Terms of Life Stress and SES on CD outcomes**

		Diabetes Outcome				Heart Disease Outcome				
	β Estimate	**OR**	**Standard Error**	**P-value**	**-2 Log L/ AIC/ c-statistic**	**β Estimate**	**OR**	**Standard Error**	**P-value**	**-2 Log L/ AIC/ c-statistic**
Life Stress * Household Income	**-0.0911**	**0.9129**	**0.0267**	**0.0007**	20,133.23/ 20,145.23/ 0.799	-0.0590	0.9427	0.0348	0.0898	12,673.94/ 12,705.94/ 0.784
Life Stress * Household Education	0.1471	1.1585	0.1544	0.3408	20,115.93/ 20,149.93/ 0.799	-0.1928	0.8246	0.1979	0.3301	12,681.06/ 12,715.06/ 0.783
Life Stress * Occupation Level	0.1520	1.1642	0.2115	0.4726	20,115.30/ 20,147.30/ 0.799	**0.5166**	**1.6763**	**0.1994**	**0.0097**	**12,661.01/ 12,693.01/ 0.784**
High Life Stress * Low Household Income	**0.6357**	**1.89**	**0.2918**	**0.0296**	**4,117.32/ 4,149.32/ 0.802**	0.8834	2.4191	0.5308	0.0964	2,734.12/ 2,766.12/ 0.781
High Life Stress * Low Household Education	0.4446	1.56	0.3811	0.2436	14,079.44/ 14,113.44/ 0.800	-0.1707	0.8430	0.3376	0.6132	8,889.62/ 8,923.62/ 0.786
High Life Stress * Low Occupation Level	-0.4602	0.6312	0.3866	0.2342	5,893.29/ 5,925.29/ 0.798	**-0.6988**	**0.4972**	**0.3219**	**0.0302**	**3,940.00/ 3,972.00/ 0.777**

Total n = 78,023 (weighted and bootstrapped sample shown only)

Our results for diabetes outcome show that models with perceived life stress and household income do have a significant interaction on a multiplicative scale (Table 8). This means that the combined effects of life stress and household income exceed the product of the exposures alone. Binary exposure variables using high perceived life stress and low household income (below Canadian median) show that the odds of having diabetes may be 89% higher for those who report having both exposures (p=0.03). On the other hand, the only significant interactions found in outcomes of heart disease were between perceived life stress and occupation level. Both exposures together showed significantly higher odds (~68%) than the product of the exposures alone ($p=0.01$). The binary variables in this case showed lower odds when high life stress and low occupation level were combined. This might be because the binary variable for "low occupation level" included those who were considered not working (valid skip) and those from the sales and service industries. Perhaps including other industries as being a lower occupation group than management, business, health, science, and law would have provided different results.

Relative Excess Risk Due to Interaction

Recall that additive interaction cannot be reported without relative risks, which are obtained from measuring the incidence of disease (VanderWeele, 2015). In order to use odds ratios in finding the additive interaction effects, we use a quantity called the "relative excess risk of interaction" (RERI), where $RERI_{RR} = RR_{11} - RR_{10} - RR_{01} + 1 \approx RERI_{OR} = OR_{11} - OR_{10} - OR_{01} + 1$. So far, only the direction of RERI (positive, negative, zero) provides us with an understanding of the combined effects of two exposures, as opposed to the actual magnitude of the value (Kalilani & Atashili, 2006). Due to the cross-sectional nature of the data used in this study, RERI could only be estimated by directly substituting the ORs for RRs in the RERI equation. This provides us with three measures: $RERI_{OR}$, the attributable portion due to interaction (AP), and the synergy index (S) (Kalilani & Atashili, 2006). RERI informs us of the excess risk due to interaction compared to the sum of the individual exposures. The attributable portion of disease is the amount of disease due to the interaction among persons with both exposures and S is the excess risk from both exposures when there is interaction relative to when there is no interaction. The interpretation of the synergy index is less applicable when the exposures are preventive exposures rather than causative (Knol, 2011).

To estimate the confidence intervals for RERI using ORs, the most robust method can be to use log linear models (Kuss, Schmidt-Pokrzywniak, & Stang, 2010); however, we found that our log linear models failed to converge when this method was used. For this reason, another approach was to use the p-value from the interaction term in the model (γ_3) (VanderWeele, 2015). Thus, the p-value from the interaction is reported along with RERI, AP, and S value below (Table 9).

Table 9: Results of the Relative Excess Risk due to Interaction (RERI) of SES and Perceived Life Stress on CD outcomes

Relative Excess Risk Due to Interaction		
	Diabetes Outcome	**Heart Disease**
Low Household Income and High Perceived Life Stress	**RERI = 0.53* [P=0.0296]** **AP = 2.685** **S = 0.60** **Positive Synergistic Effects:** joint effects are higher than individual effects	RERI = 0.61 [P=0.0964] AP = 3.615 S = 0.58 Positive Synergistic Effects: joint effects are higher than individual effects
Low Household Education and High Perceived Life Stress	RERI = 0.42 [P=0.2436] AP = 1.342 S = 0.62 Positive Synergistic Effects: joint effects are higher than individual effects	RERI = -0.04 [P=0.6132] AP = -0.018 S = 0.97 Negative Synergistic Effects: joint effects are not higher than individual effects
Low Occupation Group (Sales/Service and Not Working) And High Perceived Life Stress	RERI = -0.62 [P=0.2342] AP = -0.490 S = 0.30 Negative Synergistic Effects: joint effects are not higher than individual effects	**RERI = -1.59* [P=0.0302]** **AP = -0.545** **S = 0.55** **Negative Synergistic Effects:** joint effects are not higher than individual effects

Total n = 78,023 (weighted and bootstrapped sample shown only)

Our results show that for diabetes outcome, RERI > 0 and AP > 0 indicate that high perceived life stress and low household income variables may have positive synergistic effects—the combined effects of both are greater than the sum of individual effects (Table 9). This is the only significant RERI output from diabetes outcome. For our heart disease outcome, we found that RERI <0 and AP <0 indicate that high perceived life stress and low occupation have a lower combined effect on heart disease outcomes than the sum of the individual effects. However, it is important to note that the variable for low occupation group may not have adequately captured those belonging to lower occupational levels since individuals who were not working at the time could have previously worked in industries of management, business, health, science, and law. As well, a larger sample size is required to detect interaction effects, and the sample size for heart disease was smaller than diabetes (VanderWeele, 2015). This might have affected the interaction effects captured using our heart disease sample versus those found in our diabetes outcome.

5.0 Discussion

It is important to note that this study focused on modifiable risk factors associated with the development of CVD, as opposed to genetic (Kathiresan & Srivastava, 2012; Roca, 2015; WHO, 2005a) and geographic components (Gabb & Arnolda, 2017). We believe that workplace environment and socioeconomic circumstances are still malleable factors, although more difficult to change than daily lifestyle behaviours. It was previously assumed that the relationship between outcomes of heart disease and diabetes, perceived stress, and socioeconomic factors (including household income, household education, and occupation type) was mediated by lifestyle risk factors, specifically: physical activity levels, diet quality, smoking status, and drinking alcohol. However, present findings show that even after controlling for disease risk factors in our multivariate regression models, self-reported measures of stress and aspects of socioeconomic status remain significantly associated with self-reported outcomes of heart disease and diabetes. This indicates that the non-traditional risk factors might have an independent association with chronic disease outcomes, even when disease risk factors are accounted for. In addition, there might be an additive effect when individuals have both high stress levels and low-income levels. Thus, to decrease the existing health disparities in Canada, we may need a broader approach that goes beyond simply addressing disease risk factors. Societal factors that might be contributing to chronic disease inequalities are discussed below, along with the direction that future researchers may wish to take.

5.1 Workplace Environment

Results from our multivariate logistic regression models showed that self-reported stress at work was significantly associated to both outcomes of heart disease and diabetes, when controlling for age, sex, race/cultural background, and BMI ($p<0.0001$). However, when we added variables of socioeconomic status into the model, both occupation level and perceived stress at work were no longer significant. Once occupation level was removed from the model through step-wise backward selection, self-reported work stress again was found significantly associated with both outcomes of heart disease and diabetes. This may be due to either of the variables mediating the association, i.e. decreasing the strength of the relationship to outcomes of chronic disease. Due to the cross-sectional nature of this survey and a lack of longitudinal data on incident cases, we cannot ascertain the exact mechanisms involved in causing CDs (O'Laughlin, Martin, & Ferrer, 2018). To our knowledge, this is the first Canadian study to show that self-reported workplace stress levels are significantly associated with outcomes of self-reported heart disease and diabetes even when socioeconomic factors are accounted for in the model. Although there is an attenuation of the association between workplace stress and chronic disease outcome when occupation level is present, workplace stress does show an independent association to outcomes of heart disease and diabetes and should be addressed accordingly.

When we added additional controls using behaviour risk factors in our full multivariable regression models, we again found that workplace stress was significantly associated to outcomes of heart disease and diabetes, when occupation type was removed from the model. This shows that workplace stress is a strong, independent predictor of chronic disease outcome, even when disease risk factors are accounted for. Self-reported stress at work remains significantly associated to both diabetes and heart disease even when household income, household education, fruit and vegetable intake, smoking status, alcohol status, and physical activity status are held constant. The only possibility of mediation we see is through occupation level, which is the one aspect of SES that changed (weakened) the association between workplace stress and CD outcomes. Further research through longitudinal study designs could help to confirm this hypothesis by utilizing incident cases of heart disease and diabetes. An accurate understanding of the mediation effects in the relationship between occupation type, workplace stress, and chronic disease outcome can only be understood by collecting longitudinal data.

These results are in line with the theoretical models of workplace stress or job strain discussed in Chapter 1. As we saw in our literature review, high occupational stress indicated by high job-demands and low-control, high effort-reward imbalance, and high organizational injustice were independently associated to chronic disease outcomes due to the overactivation of the HPA axis or ANS, which can both lead to cardiometabolic dysfunction over time. This independent association should not be discounted when implementing programs on reducing incidence of chronic diseases. These results corroborate recent findings showing that workplace wellness programs might be ineffective against mitigating incidence of chronic disease outcomes (Song & Baicker, 2019; Young, 2006). Although workplace wellness programs undoubtedly benefit the physical health of employees; psychosocial stress caused by heavy workloads, long working hours, and high strain work environments can independently cause bodily damage (Carr et al., 2011). Stress is embedded in our body through changes in the ANS or HPA-axis, and this can lead to systemic organ damage that ultimately causes chronic disease over time. This may be more concerning for those who are also at a disadvantage socioeconomically, as our results from multiplicative and additive interaction showed, high stress and low income may produce cumulative effects that are higher than the product or sum of the individual exposures (Table 8,9). This could mean that high strain jobs might be especially detrimental for those also earning a low income.

5.2 Perceived Life Stress

To account for the possibility of mediation effects between occupational type and self-perceived stress at work, we added an additional variable to represent self-reported stress levels—self-perceived life stress. In our simple model of perceived life stress and outcomes of heart disease and diabetes, controlling for age, sex, race/cultural background, and BMI (Table 2), we found that perceived life stress was significantly associated to both disease outcomes ($p<0.0001$). Those who reported higher levels of life stress (quite a bit/extremely) had 59% higher odds of having heart disease than those who reported having "a bit" of life stress ($p<0.0001$). As we saw in Chapter 1, high levels of perceived stress can independently lead to maladaptive physiological changes over time via overactivation of the HPA axis or dysregulation of the ANS (Brotman et al., 2007). The cardiovascular system especially takes a toll as stress can lead to heart disease in numerous ways—endothelial dysfunction of blood vessels, calcification of arteries, decreased HRV, and increased blood pressure—which will ultimately compromise heart function over time (Brotman et al., 2007; Hintsanen et al., 2007). Thus, it is no surprise that we see such a strong cross-sectional association between self-reported levels of heart disease and perceived life stress amongst Canadians ($p<0.0001$).

Outcomes from the next multivariable logistic regression models showed us exactly what we had predicted, that perceived life stress stayed significantly associated to outcomes of heart disease and diabetes even when socioeconomic factors were added to the model (Table 4). This is the first Canadian study to show that there exists a cross-sectional association between self-reported life stress levels and outcomes of heart disease and diabetes, even when socioeconomic factors are accounted for in the model. We do see some changes in variable estimates for self-perceived life stress when socioeconomic factors are added to the model, which might indicate some mediation effects in the association between life stress levels, SES, and outcomes of chronic disease. However, we cannot make this conclusion definitively due to the cross-sectional nature of the data. It is more important to conclude from this study that both perceived stress levels and socioeconomic factors have strong independent associations to outcomes of self-reported heart disease and diabetes. Studying outcomes of chronic diseases in relation to SES or stress levels individually compromises the real-world complexity whereby individuals who have higher stress levels and lower income levels might have greater odds of developing cardiometabolic diseases.

When controlling for traditional behaviour risk factors in our model of perceived life stress and SES, we saw that both non-traditional risk factors remained significantly associated to self-reported heart disease and diabetes (Table 7). This alludes to the complexity of chronic disease outcomes and the importance of taking the social and economic environment into account when implementing programs to reduce incidence of CDs. As shown by the health impact pyramid, the most important factors in determining the success of public health initiatives are socioeconomic factors, followed by changing the context to make the individual's default decision, the healthier choice (Figure 1) (Frieden, 2010). Stressful work environments or chronic life stresses might cause maladaptive changes to our body and can also lead to making poor lifestyle behaviour choices (Hamer et al., 2008; Rugulies et al., 2008; Tsai, 2012). This is why workplace wellness programs might benefit from targeting organizational stress caused by heavy workloads, long working hours, and excessive job strain, in an effort to also improve lifestyle behaviour choices amongst employees (Carr et al., 2011; Song & Baicker, 2019). Thus far, organizations work in the opposite direction—targeting disease risk factors to improve employee health. Instead, we believe that employers should invest in changing organization structures to reduce the level of stress on employees, which could address both maladaptive lifestyle behaviours and chronic disease outcomes.

5.3 Socioeconomic Status

Studies have recognized the significant influence of socioeconomic factors on individual health outcomes for almost 50 years. As our results show, all three aspects of socioeconomic status (occupation group, household income level, and household education) were significantly associated to both outcomes of self-reported diabetes and heart disease (Table 2). As noted previously, when self-perceived stress at work was added to our multivariable logistic regression models, occupation level was no longer significantly associated with either disease outcome (Table 3). This might be due to some aspect of work itself because when perceived life stress was added to our models, we found that all three aspects of SES remained significantly associated to CD outcomes (Table 4). Surprisingly, when we adjusted for traditional disease risk factors, we found that those aspects of SES that were significantly associated to CD outcomes, in the presence of workplace stress or perceived life stress, remained as such. Although there was slight attenuation in the associations after disease risk factors were added, our models still support findings from previous literature: higher levels of household income, household education, and occupation level are found significantly associated to lower levels of both CD outcomes (Table 6,7)**.** This finding is not new in Canada, as previous studies have discussed the importance of each socioeconomic factor in relation to poor health outcomes; however, our study is the first to show that this association might exist independent of perceived stress levels and traditional disease risk factors. In addition, both multiplicative and additive interaction models showed that low levels of household income combined with high self-reported life stress might result in higher outcomes of diabetes (Table 8,9). To our knowledge, this is the first Canadian study to show the combined effects of non-traditional risk factors on chronic disease outcomes. Analysis using longitudinal data would potentially result in a deeper understanding of the combined effects and exact mechanisms (mediation pathways) by which perceived life stress and socioeconomic factors can influence CD outcomes.

Previously, it was assumed that stress or lifestyle behaviours mediate the relationship between SES and CD outcomes. As a result, more of an effort was made to address factors outside of SES when implementing initiatives for CD prevention. Our results support the need to develop innovative approaches that can affect policy and program changes to directly address socioeconomic factors. Due to previous shortcomings of awareness-based approaches, where simply educating the public about disease risk factors was thought to reduce CD incidence, new perspectives on addressing the complexity of CDs might involve taking a broader approach (Frieden, 2010; PHAC, 2015). Larger economic changes that are out of an individual's control might be addressed by implementing new policies, such as universal basic income (UBI). The World

Health Organization recently released a report on how UBI policies might address changing economic conditions and technological advances, globalization, employment and work stability, income inequality, austerity, and health inequities (WHO, 2019). This is also not a new concept in Canada; in 1975, Manitoba implemented a basic annual income randomized controlled trial to address concerns about poverty (Simpson, Mason, & Godwin, 2017). Administrative health records showed decreased hospitalization rates and mental health admissions during the four years the policy was in effect (Forget, 2011). Because no health information was collected from the study participants, only medical health records shed light on the positive health outcomes under a UBI policy. Although the province of Ontario was set to implement a basic income pilot study as well, the experiment was cut short due to concerns over funding (Simpson et al., 2017). If longitudinal data can establish an independent causal association between SES and CD outcomes, funding for a UBI policy should account for the long-term reduction of costs associated with preventing CD outcomes.

5.4 Future Direction

To better understand the complex relationship between perceived stress levels, SES, and chronic disease outcomes, direct and indirect effects should be understood through longitudinal data that can collect information on incidence of CDs. Understanding indirect effects on outcomes of CVD or T2D will inform if there is a mediator in the association with a direct causal relationship to CD outcomes. Interventions targeting CD prevention should then prioritize the direct causal factors for higher effectiveness on reducing incidence rates. For example, if we find that occupational type has nonzero direct effects and workplace stress has nonzero indirect effects, then this would suggest that workplace stress acts as a mediator between occupation type and chronic disease outcome. Interventions targeting CD prevention would then be more effective by targeting workplace stress levels instead of occupational position. Thus, future studies should consider using longitudinal data to determine the exact pathways that exist between SES, workplace stress, and CD outcomes using more complex statistical techniques such as structural equation modelling and mediation analysis. The inability to perform advanced statistical analyses using cross-sectional data shows the great need for longitudinal health data in Canada.

Since our results from multiplicative and additive interactions found positive synergistic combined effects that are greater than the product or sum of the individual effects alone, future research using data on incidence of CDs should also aim to understand the relative excess risk due to interaction between non-traditional risk factors and outcomes of chronic diseases. Our study highlights the need for greater emphasis on the non-traditional disease risk factors and addressing the root issues of chronic diseases at the organizational, societal, and global level.

5.5 Conclusion

This study concludes that non-traditional risk factors such as perceived life stress or stress at work and socioeconomic factors including household education level, occupation type, and household income level are significantly associated to outcomes of heart disease and diabetes even after controlling for traditional disease risk factors using cross-sectional survey data. Results of this study suggest that larger factors such as globalization, economic market changes, and workplace environments might influence non-traditional disease risk factors that can independently produce higher odds of chronic disease outcomes. In an effort to accurately address incidence of CDs, future studies should aim to understand the exact mechanisms of how non-traditional risk factors result in outcomes of chronic diseases.

5.6 Limitations

A cross-sectional research study has numerous limitations that must be accounted for when considering the validity and generalizability of results. The validity of results is based on the data collected by Statistics Canada and the subsequent data analysis conducted, which can introduce bias due to: one, the self-reported nature of the questions; two, linking indirect data and incorrect household variables; three, incomplete or missingness of data collected; and four, a cross-sectional observational study and nonrandomized design. On the other hand, the generalizability of the results can be compromised due to the nonrandomized sampling technique (stratified and multi-stage sampling) used by Statistics Canada to allow voluntary participation into the survey, and participation bias.

Firstly, self-reported data can introduce response bias, whereby individuals offer biased estimates of self-assessed measures due to numerous reasons including misunderstanding the question to social-desirability bias (Krumpal, 2013; Rosenman, Tennekoon, Hill, & research, 2011). Social desirability bias is a type of response bias where respondents provide an answer that would be viewed as favourable, instead of the objective truth. Due to the use of self-reported chronic disease outcomes and perceived stress levels at work and in general, we cannot ascertain if the values used in our analysis are objectively accurate.

Second, the sampling technique used data linkage between personal tax records (T1, T1FF, or T4) and tax records of all household members to report household income (Statistics Canada, 2016b). Any type of error in linking data will result in erroneous information on the variable of household income level. Moreover, the variable used for household education was supposed to represent the highest level of education for the household. Due to an error in processing, the highest level of education for the respondent was represented by the first person in the household interviewed by Statistics Canada. Thus, this variable is only true for those households where the respondent has the highest level of education; leading to an error in underestimating household education levels.

Third, missing or incomplete data collection can lead to erroneous information and producing false associations between variables. In our study, the variable for perceived stress at work had 30.2% of respondents skipping the question by "not stating" an answer. When this group was initially removed from our analysis, perceived stress at work was not found significantly associated to outcome of CDs; however, when we added the "not stated" group back into our analysis, we found this group had the highest odds of reporting heart disease and diabetes. Although we assumed that this group might not have felt comfortable reporting workplace stress levels possibly due to the stigma of mental health at work, this variable could also have produced a spurious association due to a 30% missingness of known information.

The final aspect that could compromise the validity our results was at the data analysis stage where we could not control for all possible confounders that might influence CD outcomes, such as living in rural versus urban areas, regular physician contact, immigration status, marital status, etcetera. Due to statistical constraints of model complexity and producing accurate results, we chose to include only those factors that were considered to be better predictors of chronic disease outcomes. However, a nonrandomized, cross-sectional, observational study should try to incorporate as many controls as allowed within good model diagnostics to account for confounding and spurious associations. Although our models did incorporate numerous controls and we built step-wise on previous models with more controls, we are aware of the limitation that there might be some confounders that were not accounted for in our models. Thus, it is difficult to assume if the association derived from our models is a true association or due to confounding by unknown factors. In addition, the nonrandomized design of the study required the use of bootstrapping techniques to improve the precision of confidence intervals, standard errors, and odds ratios.

However, it should be noted that bootstrapping is an approximate method and no statistical technique can provide perfect accuracy (Haans, 2019).

Lastly, the generalizability of the results could be compromised due to nonresponse generating an unrepresentative sample. Although stratification and multi-stage sampling aims to increase representation across all health regions, these techniques cannot address issues related to nonresponse, which may be more pronounced in certain areas. In addition, the voluntary nature of this survey may introduce participation bias, whereby those who agree to participate in a research study may be inherently different from those who decline (Junghans & Jones, 2007). We could not control who volunteered to participate in the national survey, and thus the sample may not be truly generalizable to all Canadian sub-populations. Because certain subpopulations were excluded from the sample (such as persons living on Aboriginal reserves and First Nation settlements), we also cannot generalize to those sub-populations who were excluded from the CCHS.

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Appendix A

Variables included from CCHS 2015-2016	
Dependent variable (disease outcome)	
Variable CCC_095:	Do you have heart disease
Variable CCC_085:	Do you have diabetes
Independent variables (controls)	
Variable DHH_AGE:	Age
Variable DHH_SEX:	Sex
Variable SDCDVCGT:	Cultural or racial background
Variable HWTDVCOR:	Body mass index (adjusted)
Independent variables	
Variable EHG2DVH9:	Highest level of education - household 9 levels
Variable INCDVHH:	Total household income - all sources
Variable LBFDVOCG:	Occupation group
Variable GEN_025:	Perceived stress at work
Variable GEN_020:	Perceived life stress
Independent variables (disease risk factors)	
Variable FVCDVGDT:	Total daily consumption - fruits and vegetables
Variable PAADVAC2:	Alternate physical activity indicator
Variable SMK_005:	Type of smoker – presently
Variable ALCDVTTM:	Type of drinker (12 months)