BLOOD PRESSURE CONTROL AMONG CANADIANS WITH HYPERTENSION, WITH AND WITHOUT DIABETES

by

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Abstract

The thesis offers the following contributions to the epidemiology of hypertension in Canada:

1. The first manuscript uses cross-sectional data from the *2007-2009 Canadian Health Measures Survey* (CHMS) to compare the prevalence of controlled hypertension between people with and without diabetes. Of the 74% of Canadians with diabetes who had hypertension, 56% (95% CI: 45%-66%) had controlled blood pressure compared to 64% (95% CI: 58%-69%) of Canadians without diabetes. Among people taking medication, individuals with diabetes were less likely to have controlled hypertension ($OR_{adjusted}$: 0.3; 95% CI: 0.2-0.6).

2. The objective of the second manuscript was to determine, among Canadians with hypertension, whether individuals with diabetes were less likely than those without to recall health professional advice for healthy behaviours and whether receipt of such advice influences behaviour, using cross-sectional data from the *2009 Survey on Living with Chronic Diseases in Canada (SLCDC)*. Canadians with diabetes were more likely than those without to recall advice to control/lose weight (81% vs. 66%), exercise (79% vs. 68%), limit alcohol (78% vs. 55%) and modify diet (70% vs. 61%) but not limit salt (65% vs. 64%). Both groups were equally likely to report following advice, with receipt of advice positively associated with engagement in healthy behaviours.

3. The third manuscript describes knowledge of blood pressure targets in Canadians with hypertension using cross-sectional data from the *2009 SLCDC.* Knowledge of blood pressure targets was low, with 28% and 32% of Canadians with and without diabetes

reporting having discussed a blood pressure target and reporting a target in line with clinical practice guidelines.

4. The fourth manuscript validates an existing self-reported blood pressure control question in a sample of 161 patients with hypertension in Kingston. In people with and without diabetes, the question had sensitivities of 83% ± 11% and 78% ± 10% and specificities of 30% ±19% and 58% ± 21%, respectively.
5. The final manuscript tests a method designed to account for misclassification in epidemiologic studies, using data from the CHMS. The method was found to perform inconsistently in multivariate contexts and introduced bias when minor differential misclassification was ignored.

Co-Authorship

This thesis presents the work of Marianne Gee in collaboration with her advisors, Dr. William Pickett, Dr. Ian Janssen, Dr. Norm Campbell, and invited co-authors.

Manuscript 1: The idea of using the *Canadian Health Measures Survey* to examine prevalence of blood pressure control in Canadians with hypertension was Marianne Gee's and Dr. Campbell's. Marianne Gee developed the analytic plan, analyzed the data and wrote the manuscript. Dr. Campbell, Dr. Janssen, Dr. Pickett, Dr. McAlister and Dr. Bancej contributed to the analytic plan and the discussion. Dr. Joffres and Dr. Johansen reviewed and edited the manuscript. This manuscript is published in the *Canadian Journal of Cardiology* (Citation: Gee ME, Janssen I, Pickett W, McAlister FA, Bancej CM, Joffres M, Johansen H, Campbell NRC. Prevalence, awareness, treatment and control of hypertension among Canadian adults with diabetes, 2007-2009. Canadian Journal of Cardiology. 2012; 28(3): 367-74).

Manuscript 2: Marianne Gee conceptualized the idea of exploring the association between receipt of physician advice and engagement in health behaviours in people with and without diabetes using the 2009 *Survey on Living with Chronic Diseases in Canada*. The idea of developing a score measures of advice and behaviour was Dr. Pickett's. Marianne Gee analyzed the data and wrote the manuscript. Dr. Pickett, Dr. Janssen, Dr. Johnson, and Dr. Campbell contributed to the manuscript. This manuscript is published in the *Journal of Clinical Hypertension.* (Citation: Gee ME, Pickett W, Janssen I, Johnson JA, Campbell NRC. Health behaviors for hypertension management in people with and without coexisting diabetes. Journal of Clinical Hypertension. 2013 Jun;15(6):389-96)

Manuscript 3: The idea of describing knowledge of blood pressure targets and their impact on achieved blood pressure control was Marianne Gee's. Marianne Gee developed the analytic plan, analyzed the data and wrote the short report. Dr. Pickett, Dr. Janssen, and Dr. Campbell reviewed, edited, and contributed to the manuscript.

Manuscript 4: The idea of validating the self-reported measure of blood pressure control from the *Survey on Living with Chronic Disease in Canada* was Marianne Gee's. Marianne Gee designed the study, recruited participants, conducted the interviews and chart reviews, analyzed the data, and wrote the manuscript. Dr. Pickett, Dr. Janssen, Dr. Campbell, and Dr. Birtwhistle contributed to the design of the study and reviewed, edited and contributed to the development of the manuscript. This manuscript is accepted, in press in *Blood Pressure Monitoring*.

Manuscript 5: The idea of applying and demonstrating the use of the probabilistic sensitivity analysis was Marianne Gee's. The idea of using the *Canadian Health Measures Survey* was Dr. Janssen's. Marianne Gee developed the analytic plan together with Dr. Janssen and Dr. Pickett. Marianne Gee analyzed the data and wrote the manuscript. Dr. Pickett and Dr. Janssen reviewed, edited and contributed to the development of the manuscript. Dr. Campbell reviewed the manuscript.

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I can only aspire to be as good.

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List of Abbreviations

mmHg – millimetres of mercury

g – gram

mg – milligram

OR – odds ratio

PR – prevalence ratio

RR – relative risk

CI – confidence interval

s.e. – standard error

BMI – body mass index

CHMS – Canadian Health Measures Survey

SLCDC – Survey on Living with Chronic Diseases in Canada

QFHT – Queen's Family Health Team

Chapter 1

Introduction

1.1 General overview

Hypertension, or high blood pressure, is a prevalent and important risk factor for premature mortality in Canada. Hypertension is a condition in which blood pressure is chronically elevated, and is clinically diagnosed when systolic blood pressure is 140 mmHg or greater or diastolic blood pressure is 90 mmHg or greater on multiple physician visits (1). Individuals with hypertension are at 2-3 fold increased risks for cardiovascular disease (2). Hypertension also clusters with other cardio-metabolic conditions, namely diabetes, dyslipidemia, insulin resistance, glucose intolerance and obesity (2), which together increase cardiovascular disease risk (3-5). In 2007-2008, approximately 6 million Canadian adults had been diagnosed with hypertension (20% of the adult population), projected to increase to 7.4 million (26%) by 2012-2013 (6).

Due to its associated risks, it is important that high blood pressure be diagnosed, lowered and controlled (7). Current clinical practice guidelines in Canada recommend that adults with hypertension lower and maintain their blood pressure below 140/90 mmHg using pharmacotherapy and/or lifestyle modification (8). The recommended target blood pressure for people with diabetes is below 130/80 mmHg (8, 9).

1.1.1 Burden of disease related to uncontrolled high blood pressure

Worldwide, in 2010, uncontrolled high blood pressure accounted for 9.4 million deaths and 174 million disability-adjusted life years lost, making it a leading risk factor global disease (10). Approximately 54% of strokes, 47% of ischemic heart disease, and 25% of other cardiovascular diseases have been attributed to suboptimal control of blood pressure (11). Controlling blood pressure reduces the risk of cardiovascular disease: in their meta-analysis of 147 randomised controlled trials, Law *et al.* showed that a blood pressure reduction of -10 mmHg/-5 mmHg significantly reduced the risk of stroke by 46% and the risk of coronary heart disease by 21% (12). Likewise, many population-based cohort studies have demonstrated an increased risk for cardiovascular disease and death associated with high blood pressure (13); for example, a follow-up of the *National Health Nutrition and Examination Survey* in the United States showed that, compared to normotensive Americans, people with uncontrolled high blood pressure had a higher relative risk for cardiovascular disease mortality (RR: 1.74; 95% CI: 1.28-2.49) than hypertensive people with controlled blood pressure (RR: 1.15; 95% CI: 0.79-1.80) (14). Approximately 1 in 3 Canadians with hypertension have uncontrolled high blood pressure and, among people taking medication for hypertension, approximately 20% have uncontrolled high blood pressure (15).

1.1.2 Blood pressure control in diabetes

Hypertension disproportionately increases risks for cardiovascular disease in people with diabetes (16-18) and is highly prevalent, affecting 40-80% of this subpopulation (17). Despite its associated risks, blood pressure control may be lower in people with diabetes. The *Canadian Heart Health Survey* (conducted between1986 and 1992) showed that less than 10% of people with diabetes had treated blood pressures lower than 140/90 mmHg (19). In Ontario in 2006, individuals with diabetes were less likely to have their blood pressure controlled below 140/90 mmHg compared to individuals with other chronic conditions and individuals without these conditions (20). It is unclear whether this disparity extends to the rest of Canada.

1.1.3 Management of hypertension

Not only is it important to understand *whether* blood pressure needs to be improved in people with diabetes, it is also important to determine *how* blood pressure can be improved in this group (i.e., to try to identify *why* people with diabetes are more likely to have uncontrolled high blood pressure.) Healthy lifestyle changes are a cornerstone of hypertension management. People with hypertension are recommended to: 1) reduce dietary salt to 1500 mg/day or less depending on age; 2) eat a healthy diet; 3) limit alcohol consumption; 4) participate in aerobic exercise; 5) attain or maintain a healthy body weight, and 6) use stress management strategies where needed (8, 21). Patients who are advised by their health professional to make these changes may be more likely to do so (22, 23). Lack of adherence to healthy behaviour changes, and lower receipt of advice for these behaviours, may explain lower blood pressure control rates in people with diabetes.

1.1.4 Measurement of blood pressure control in national population-based surveys in Canada

National surveys offer a means to identify groups at risk for uncontrolled hypertension (such as people with diabetes) as well potential reasons for these disparities, with results used to inform national efforts to control hypertension (24). At the national level, surveillance of hypertension has historically relied on the *Canadian Community Health Survey* (a self-reported ongoing national survey conducted since 2000 and preceded by the *National Population Health Survey*). Another source of national surveillance information is the *Canadian Chronic Disease Surveillance System* which uses provincial and territorial health administrative databases (i.e., physician billing, hospitalization and resident registries) to estimate the incidence, prevalence, and all-cause mortality associated with diagnosed hypertension (25). Although useful for examining associations and trends in diagnosed hypertension, neither data sources measures undiagnosed hypertension nor uncontrolled high blood pressure. In 2007, the federal government initiated the *Canadian Health Measures Survey*, a survey that includes measures of blood pressure and allows prevalence of hypertension, awareness, treatment and control to be assessed at the national level for the first time since the *Canadian Heart Health Survey* in 1986-1992. Furthermore, in 2009, the federal government developed and fielded the hypertension component of the 2009 *Survey on Living with Chronic Diseases in Canada* (SLCDC), a survey designed partly to examine how Canadians with hypertension are managing their condition (26). As part of the survey, respondents were asked to self-report their level of blood pressure control; it is unclear whether this is a valid way to measure blood pressure control.

1.2 Aim

The aim of the thesis was to better understand the distribution and determinants of blood pressure control in Canadians with diabetes. To meet this aim, the thesis had the following objectives:

1.2.1 Descriptive objective:

The descriptive objective of the thesis was to determine whether prevalence, awareness, treatment and control of hypertension differ between individuals with and without diabetes.

1.2.2 Etiologic Objective:

The etiologic objective of the thesis was to test the hypothesis that the disparity in blood pressure control between people with and without diabetes is due to lower engagement in healthy behaviour changes, influenced by receipt of clinical advice for the behaviours, as depicted in Figure 1. Specifically, I sought to determine, using a large population-based survey of people with hypertension, whether 1) receipt of clinical advice for non-pharmacological management strategies and 2) engagement in these strategies differ between individuals with and without diabetes. I also examined whether knowledge of blood pressure targets differs between these groups.

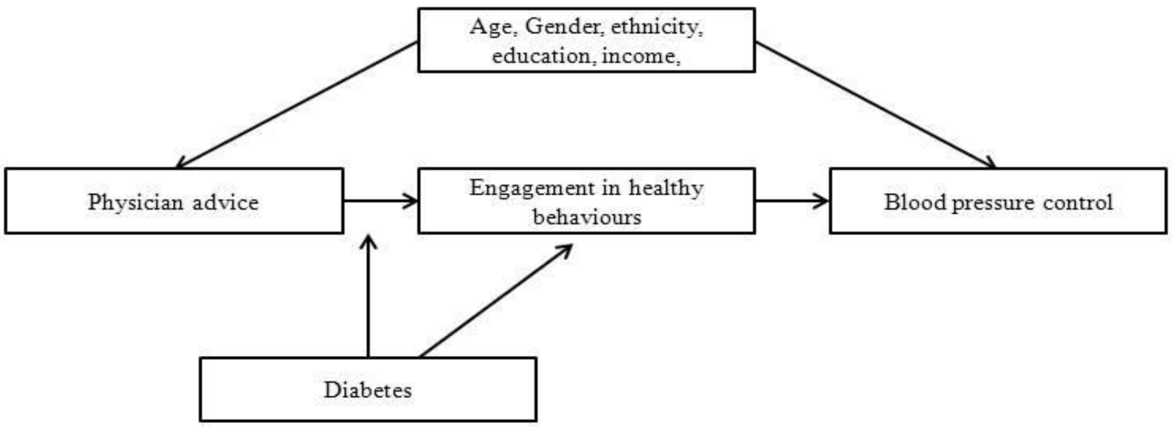

Figure 2-1 Conceptual Model. Receipt of physician advice may impact on patient adherence to health behaviour change and subsequently on blood pressure control. Presence of diabetes may influence receipt of advice and/or engagement in health behaviours or may modify the relationship between these factors.

1.2.3 Methodological objectives:

In order to relate receipt of clinical advice and engagement in healthy behaviours to observed diabetes-related disparities in blood pressure control, I first needed to validate the self-reported measure of blood pressure control included in the *2009 Survey on Living with Chronic Disease in Canada*. The original intent had been to use the validation results to quantify the amount of bias and uncertainty introduced by self-reported blood pressure control in association with receipt of advice using a published probabilistic sensitivity analysis method (27). However, when applied, the estimates of sensitivity and specificity did not produce meaningful estimates; this issue is discussed in the General Discussion (Chapter 8).

Instead, as a secondary methodological objective, I evaluated a probabilistic sensitivity analysis method that has been recently developed to quantify the amount of bias and uncertainty introduced to associations by misclassification. I compared self-reported body mass index and physical activity with objective measures to estimate sensitivity and specificity and used these data to test the quantitative assessment of bias, in relationships with hypertension and uncontrolled high blood pressure, using a published probabilistic sensitivity analysis method (27).

1.3 Rationale

1.3.1 Rationale for the descriptive objective

In 2007, the Canadian Hypertension Education Program and the Canadian Diabetes Association, among others, called on health care professionals to redouble their efforts in helping patients with diabetes achieve appropriate blood pressure targets (11), based on previous findings from the *Ontario Blood Pressure Study*, which showed that people with diabetes were less likely to have their blood pressure controlled below 140/90 mmHg (20). I sought to determine whether the findings in Ontario extend to the rest of Canada. The *Canadian Health Measures Survey*, initiated in 2007, provided an opportunity to determine whether Canadians with diabetes were less likely to have their blood pressure controlled, compared to those without.

1.3.2 Rationale for the etiologic objective

People who are advised by their health professional to make healthy lifestyle changes, such as reducing dietary salt, changing diet, exercising, or losing weight, may be more likely to do so

(22,23). Understanding the extent to which healthy behaviours are recommended by clinicians and followed by individuals with both diabetes and hypertension may identify areas for intervention to reduce previously observed disparities in blood pressure control. Small reductions in blood pressure in persons with and without diabetes (-6/-4.6 mmHg and –3.7/–3.3 mmHg, respectively) have been associated with 13% and 24% reductions in major cardiovascular events and total stroke events, respectively (28); hence, improving blood pressure control in Canadians will undoubtedly have a positive impact on cardiovascular disease and stroke prevention. Understanding how physician advice relates to patients' behaviours for blood pressure control and whether people with diabetes are less likely to receive and follow such advice may support initiatives designed to support health care professionals in educating their patients and tailored to the needs of people with diabetes.

1.3.3 Rationale for the methodological objective

In order to further understand blood pressure control at the national level, I sought to validate the self-reported measure of blood pressure control included in the 2009 (and 2011) *Survey on Living with Chronic Diseases in Canada*. The hope was that, by quantifying its accuracy, I and other researchers would be able to use these surveys to identify determinants of blood pressure control in a large nationally-representative sample. Furthermore, I hoped that the results of the validation study would allow researchers to mathematically account for imperfect sensitivity and specificity in estimates of association. One way to do this is by using probabilistic sensitivity analyses to quantify the amount of bias and imprecision introduced to odds ratios by a misclassified exposure or outcome (27). To my knowledge no study has shown that this method can estimate associations based on 'gold-standard' exposures (thereby quantifying bias accurately) or demonstrated the implications of improperly specifying misclassification parameters using real data.

1.4 Thesis organization

This thesis conforms to the regulations outlined in the Queen's School of Graduate Studies and Research "General Forms of Theses" and is structured as a manuscript-based thesis. The second chapter is a literature review that provides a general overview of the problem of blood pressure control in diabetes and review existing research examining the relationship between physician communication and blood pressure control. Following the literature review, 5 manuscripts are included. The first manuscript (Chapter 3) describes and compares prevalence, awareness, treatment and control of hypertension among Canadians with and without diabetes. The second manuscript (Chapter 4) explores the relationship between having received advice for lifestyle behaviour change and engagement in healthy behaviours for blood pressure control, among Canadians with hypertension with and without diabetes. The third manuscript (Chapter 5) is a short report that describes the extent to which Canadians with hypertension have discussed a target blood pressure with a health professional and can recall the recommended blood pressure targets. The fourth manuscript (Chapter 6) validates an existing self-reported measure of blood pressure control (from the 2009 *Survey on Living with Chronic Disease in Canada)* in a sample of people with hypertension with and without diabetes attending the Queen's Family Health Team clinic. The fifth and final manuscript (Chapter 7) evaluates a probabilistic sensitivity analysis method that has been developed to quantify the amount of bias and uncertainty introduced to associations by misclassification. A general discussion is provided in Chapter 8.

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Chapter 2

Background and Literature Review

The purpose of this chapter is to 1) outline the key definitions used throughout the thesis; 2) describe the problem of blood pressure control in diabetes; 3) describe the recommended treatments for hypertension and engagement in these behaviours among people with hypertension, and specifically those with and without diabetes; 4) review studies examining the role of physician advice in promoting health behaviour change for blood pressure control and the extent to which advice is provided and followed by people with hypertension; and 5) review key methods for measuring blood pressure. This chapter is not intended to be an exhaustive review of the literature, but rather is meant to orient the reader to some of the main issues addressed within the thesis.

2.1 Key definitions

Throughout the thesis, ***blood pressure*** refers to the force that the circulating blood exerts on the arteries; it is the product of the amount of blood pumped by the heart per unit of time and the force of the peripheral arteries opposing the circulation of blood. ***Systolic blood pressure*** is the peak pressure exerted by the circulating blood when the heart contracts. ***Diastolic blood pressure*** is the trough pressure exerted when the heart is relaxed. Throughout the thesis the terms ***hypertension*** and ***high blood pressure*** are often used synonymously, and refer to the presence of blood pressure that is chronically elevated. For the general population, hypertension is diagnosed when systolic blood pressure is 140 mmHg or greater or diastolic blood pressure is 90 mmHg or greater on multiple physician visits; in Canada, for individuals with diabetes, hypertension is diagnosed according to a 130/80 mmHg threshold (1). ***Diabetes*** is a metabolic disorder characterized by chronic hyperglycemia (i.e. elevated blood glucose) as a result of defective insulin secretion and/or defective insulin action (2). For the purpose of this research, type 1 and type 2 diabetes are not distinguished; type 2 diabetes represents 90% to 95% of cases (3). For the purposes of this research, gestational diabetes (i.e. glucose intolerance during pregnancy) is excluded from the definition of diabetes.

Blood pressure control refers to having systolic blood pressure controlled below 140 mmHg and diastolic blood pressure controlled below 90 mmHg among adults who have been diagnosed with hypertension (4). For adults with diabetes, blood pressure control is defined according to a 130/80 mmHg threshold (2, 4). New in 2013, the Canadian guidelines now recommend patients aged 80 years or older with isolated systolic hypertension be treated to a systolic blood pressure target < 150 mmHg rather than < 140 mmHg (5).

The terms ***antihypertensive medication*** and ***antihypertensive pharmacotherapy*** are used interchangeably and these refer to medications prescribed to lower blood pressure. The terms ***lifestyle changes, healthy behaviours,*** and ***non-pharmacological therapy*** are also used interchangeably and refer to lifestyle behaviours currently recommended for the treatment of blood pressure. These are to 1) reduce dietary salt to 1500 mg/day or less depending on age; 2) eat a healthy diet; 3) limit alcohol consumption; 4) participate in aerobic exercise; 5) attain or maintain a healthy body weight, 6) use stress management strategies where needed, as later described in detail (4,6).

2.2 Blood pressure control in diabetes

2.2.1 Importance of blood pressure control in diabetes

Hypertension is one of the leading risk factors for development of cardiovascular disease in people with diabetes (7) and is estimated to account for 30% of all cause deaths and 25% of cardiovascular events in this population (8). In people with diabetes, the presence of hypertension is associated with a 90% increase in the risk of cardiovascular disease death, 89% increase in the risk of myocardial infarction, 57% increase in risk of stroke, and 78% increase in risk of heart failure (8), a risk that is disproportionately higher than that observed for either condition alone (9). The presence of hypertension in people with diabetes also increases the risk of peripheral arterial disease, end stage renal disease, and microvascular complications such as retinopathy (7). Hypertension affects 40% to 80% of people with diabetes (7), making the control of blood pressure an important priority. However, uncertainties exist around the optimal blood pressure target for people with diabetes.

2.2.2 Blood pressure targets for people with diabetes

In North America, clinical practice guidelines have recommended that people with diabetes control their blood pressure to <130/80 mmHg (2,5,6,11,12), historically informed by observational studies (13-15), whereas for the general population the blood pressure control target is <140/90 mmHg, largely informed by randomized control trial findings. In 2010, the *Action to Control Cardiovascular Risk in Diabetes* (ACCORD) randomized controlled trial raised questions about the optimal target for blood pressure control in diabetes (16). The trial found that systolic blood pressure control <120 mmHg conferred benefit in terms of stroke incidence but not cardiovascular events (the primary endpoint), while increasing the risk of serious but rare treatment-related adverse events, namely hypotension, bradycardia/arrhythmia, and hyperkalemia (16). The study also showed, in a supplementary appendix, that in the group randomized to routine glycemic control, those further randomized to the lower blood pressure appeared to have a statistically significant reduction in cardiovascular events (16).

Three meta-analyses (17-19) have since evaluated whether blood pressure should be controlled to <130/80 mmHg in patients with diabetes. In their meta-analysis, Bangalore *et al.* showed that systolic blood pressure <130 mmHg reduced the likelihood of stroke (0.53; 95% CI: 0.38-0.75), while also showing significant increased odds of adverse events (17). Likewise, McBrien *et al.* (18) showed that blood pressure control <130/80 mmHg was significantly associated with a decreased risk of stroke (relative risk [RR]: 0.65; 95% CI: 0.48-0.86) but was not significantly related to all-cause mortality (RR: 0.76; 95% CI: 0.55-1.05) or myocardial infarction (RR: 0.93; 95% CI: 0.80-1.08). Based on my calculations, this meta-analysis had 83% power to detect the effect for stroke, 79% power to detect the effect for mortality, and 14% power to detect the effect for myocardial infarction and was largely influenced by ACCORD which had a sample size that was 4-8 times greater than the other included trials. In a meta-analysis of 73,913 people with diabetes, Riboldi *et al.* found that risk of stroke decreased by 13% for every 5 mmHg reduction in systolic blood pressure and by 12% for each 2 mmHg reduction in diastolic blood pressure (19). These meta-analyses did not consider the potential interaction between blood pressure control and glycemic control, as observed in the ACCORD trial.

Weighing evidence of a protective effect for stroke against the increased risk of rare adverse events (20), the Canadian guidelines continue to recommend a treatment target of <130/80 mmHg for people with diabetes (5, 12). Other groups, such as the American Diabetes Association have revised their guidelines to recommend that hypertension be treated to <140/80 mmHg and that a lower systolic target of <130 mmHg may be appropriate if achieved without undue treatment burden (21).

2.2.3 Achievement of blood pressure control in diabetes

Findings from Ontario (22) and the United States (23) have suggested that individuals with diabetes are less likely to have their blood pressure controlled compared to individuals without diabetes, even when defined based on the general population target of <140/90 mmHg. In Ontario in 2006, 59% of individuals with diabetes had their blood pressure controlled below 140/90 mmHg compared to 66% and 74% of individuals with no comorbidity or other comorbidity (cardiovascular or kidney disease), respectively. These differences did not reach statistical significance in bivariate or multivariate analyses; according to the authors, none of the potential predictors (including age, sex, ethnic background, body mass index and number of antihypertensive medications) were statistically significant due to insufficient sample size (22). Data from the 1999-2004 cycles of the *National Health Examination and Nutrition Survey* in the United States also showed that individuals with diabetes were less likely to have controlled blood pressure (OR: 0.5; 95% CI: 0.3 to 0.9) compared to individuals without diabetes, after accounting for sex, age, number of physician visits, timing of most recent blood pressure measurement, insurance coverage, body mass index, and presence of kidney disease or cardiovascular disease (23). Blood pressure control among people with diabetes has not been described at the national level in Canada since 1992; at that time less than 10% had treated blood pressures <140/90 mmHg (24). Prevalence of blood pressure control in Canadians with and without diabetes is compared in Chapter 3.

2.3 Causes of uncontrolled high blood pressure

It remains unclear why individuals with diabetes may have poorer rates of control. Blood pressure may be more difficult to control in individuals with diabetes due to pathophysiological differences, and in many cases multiple antihypertensive medications are required to control blood pressure (25). Lack of adherence to medication and healthy behaviour changes and lower receipt of advice for these behaviours, could potentially explain lower blood pressure control rates in people with diabetes.

2.3.1 Pathophysiological differences in diabetes

As previously stated, blood pressure is the result of the amount of blood pumped by the heart per unit of time (cardiac output) and the force of the peripheral arteries opposing the circulation of blood (peripheral resistance). To keep blood pressure responsive and within a normal range, cardiac output and peripheral resistance are under the tight control of a complex feedback system that involves the interplay of the sympathetic and parasympathetic nervous systems, the renin-angiotensin-aldosterone system, and other vasoactive mechanisms (26). Although there are many pathophysiological processes that can lead to the development of hypertension (26), most of which are beyond the scope of this review, mechanisms related specifically to the presence of diabetes may involve excess circulating insulin.

Excess circulating insulin, arising from insulin resistance in diabetes, may increase blood pressure by stimulating the sympathetic nervous system, acting as a growth factor, and/or increasing sodium reabsorption in the kidneys (26). In simple terms, the release of insulin following a meal stimulates vasodilation (the widening of blood vessels) in skeletal muscle while also activating the sympathetic nervous causing vasoconstriction (27). In most people, these opposing effects have a minimal net effect on blood pressure. In people with diabetes or insulin resistance, however, excess circulating insulin (hyperinsulinaemia) may result in decreased vasodilation and increased vasoconstriction, with the net effect of raising blood pressure (27). Insulin is also a growth factor and long-term excess circulating insulin may trigger cell proliferation in the vascular wall, which may lead to arterial stiffness and increased vascular resistance (28). Finally, hyperinsulinaemia can also cause an increase in blood volume (28), by enhancing sodium retention during hyperglycemia (uncontrolled high blood glucose) and subsequent fluid retention (29).

2.3.2 Resistant hypertension

Resistant hypertension is characterized by uncontrolled high blood pressure despite concurrent use of 3 or more different antihypertensive drug classes (30). In Canada, among people with hypertension, approximately 4.4%-7.8% are estimated to have resistant hypertension (or 22.3% - 29.0% of people with treated but uncontrolled high blood pressure) (31). People who develop resistant hypertension are more likely to have diabetes at first diagnosis (32). In a recent analysis of people taking 3+ antihypertensive medication classes (n=2602), people with uncontrolled high blood pressure (i.e., resistant hypertension) were not more likely to be obese, physically inactive, current smokers, consume high amounts of alcohol, or adhere to the Dietary Approaches to Stop

Hypertension (DASH) diet (33), behaviours currently recommended for control of blood pressure.

2.3.3 Adherence to treatments for hypertension

Control of blood pressure is multifactorial, with a number of antihypertensive medications and health behaviours having been shown to lower blood pressure in randomized controlled trials. The Canadian Hypertension Education Program guidelines recommend that Canadians with hypertension be treated with antihypertensive medication and/or make healthy lifestyle changes to lower and control blood pressure (5).

2.3.3.1 Medication adherence

With respect to antihypertensive medications, the Canadian guidelines recommend initial monotherapy (treatment with 1 medication) using a thiazide diuretic, a β-blocker (in patients younger than 60 years), an angiotensin-converting enzyme inhibitor (in non-black patients), a long-acting calcium channel blocker or an angiotensin receptor blocker. If target blood pressures are not achieved with monotherapy, additional first-line antihypertensive medications should be initiated (5).

Historically, lack of diagnosis and lack of medication treatment have been significant sources of uncontrolled high blood pressure at the population level in Canada. In 1986-1992, 43% of Canadians with hypertension were unaware of having the condition and 22% were aware but untreated, compared to 17% and 4% in 2007-2009 (34). Similar improvements have occurred in people with diabetes (34). While treatment rates have improved substantially, approximately

14% of Canadians with hypertension are treated with medication but have uncontrolled high blood pressure (35). Among those treated, lack of control may relate to the failure of health professionals to intensify pharmacotherapy or lack of adherence to prescribed medications (36).

People with diabetes often require more antihypertensive medication to achieve target blood pressures than people without (37). Results from clinical trials suggest that 2 or more different antihypertensive medications are required in >65% of patients with diabetes to achieve blood pressure control (37) yet in Ontario in 2001, 32% of people with both diabetes and hypertension were treated with more than one medication within 2 years of diagnosis, based on linkage of the Ontario Diabetes Database and the Ontario Drug Benefit database (38). In a self-reported survey of Ontario in 2006, 54% of people with diabetes and hypertension were taking 2+ antihypertensive medications, of whom 46% had controlled blood pressure based on automated blood pressure measurements (39). This is compared to the 49% of people without diabetes on 2+ medications, of whom 90% ($p<0.05$) were controlled (39). Medication treatment patterns in Canadians with diabetes in 2007-2009 are explored in Chapter 3.

Even when appropriate medications are prescribed, lack of blood pressure control may result from non-adherence to the prescribed medications. In Canada in 2009, 88% of Canadians with self-reported diagnosed hypertension reported taking their antihypertensive medication as prescribed, with 10% reporting that they occasionally miss a dose; the most commonly reported reason for occasionally missing a dose was that respondents “forget to take it” (88%) (40). People who reported occasionally missing doses of their medication were more likely to report borderline or high blood pressure, but the likelihood of missing doses of medication did not differ by diabetes status (40). In a survey of American adults in 2005, 28% of respondents who had ever being prescribed antihypertensive medication reported having difficulty taking their medication (41). In that survey, while "not remembering" was also the most commonly reported barrier (32%), cost (23%), lack of insurance (22%), side effects (13%), and not feeling the need to take medication (9%) were also important barriers. People with diabetes were not more likely to report difficulty in taking medication (41).

While antihypertensive treatment and adherence are important components of blood pressure control, healthy lifestyle changes also aid in control (5). Non-pharmacological management is recommended for all people with hypertension and can be used as stand-alone therapy for people with blood pressures <160/100 mmHg in the absence of target organ damage or cardiovascular disease risk factors (5). Lack of adherence to these behaviours, namely increased physical activity, adherence to a healthy diet, weight loss, sodium restriction, limited alcohol consumption, smoking cessation, and stress management (as described in detail below) could potentially explain lower blood pressure control rates in people with diabetes.

2.3.3.2 Physical activity

Exercise has both an acute and chronic effect of lowering blood pressure (42). In a meta-analysis of 72 randomized controlled trials, Cornelissen and Fagard found that aerobic exercise training was associated with a -6.9/-4.9 mmHg decrease in resting ambulatory blood pressures in people with hypertension (43); in that meta-analysis, exercise training interventions varied in terms of duration (4-52 weeks, average of 40 weeks), frequency (1-7 days/week, 3 times/week), length (15-63 minutes, average 40 minutes), and intensity (30% - 88% of heart rate reserve, average

65%). Despite the wide variation in the training programs, the authors found that the individual training program characteristics were not predictive of the blood pressure response. The Canadian Hypertension Education Program guidelines recommend that people with hypertension engage in 30 to 60 minutes of moderate intensity aerobic exercise four to seven days per week to help control their blood pressure (5). Recently, the C-CHANGE initiative (Canadian Cardiovascular Harmonization of National Guidelines Endeavour) has recommended that adults accumulate at least 150 min of moderate-to-vigorous-intensity aerobic physical activity per week, in bouts of 10 min or more, to achieve health benefits (12). This is consistent with the Canadian guidelines for physical activity in adults and older adults (44), which is based on a systematic review of the effects of physical activity on incidence of premature mortality and seven chronic conditions, including hypertension (45).

Despite its strong effects, few people with hypertension meet physical activity recommendations. An analysis of the *National Population Health Survey* from 1994-2002 showed that few Canadians changed their physical activity behaviour following diagnosis of hypertension, with 39% physically active before diagnosis and 44% physically active after diagnosis, based on self-report (46). I previously showed that 46% of Canadians with hypertension reported engaging in physical activity all or most of the time to help control their blood pressure (47). Lower engagement in physical activity has been reported in the United States; in 1999-2004, 26% of Americans with hypertension reported being physically active as part of the *National Health and Nutrition Examination Survey* (48). Only one study, to my knowledge, has compared physical activity between people with and without diabetes among people with hypertension; Egede showed that, among Americans diagnosed with hypertension in 1998, people with and without diabetes were equally likely to report exercising currently (78% vs. 81%) in response to advice from their doctor (49).

2.3.3.3 Dietary change

Canadians with hypertension are recommended to make dietary changes that emphasize fruits, vegetables and low-fat dairy products, dietary and soluble fibre, whole grains and protein from plant sources, and foods that are low in saturated fat and cholesterol (5). This is largely based on the Dietary Approaches to Stop Hypertension (DASH) trials, the first of which compared the effects of three dietary patterns on blood pressure (without considering sodium): 1) a typical American diet; 2) a typical American diet plus fruits and vegetables (5 and 4 servings/day respectively); and 3) a combination diet that emphasized fruits, vegetables, low-fat dairy, whole grains, poultry, fish and nuts (50). The latter, now commonly referred to as a Mediterranean or DASH diet, was lower in red meat, snacks and sweets, oils and fats, and was higher in fibre, potassium, magnesium, and calcium. All diets had a similar amount of sodium (3000 mg/day) (50). In the subpopulation with stage 1 hypertension (i.e. blood pressures ≥ 140/90 mmHg but <160/95 mmHg) the DASH diet resulted in a -11.4/-5.5 mmHg change in ambulatory blood pressures (50). In people with diabetes, adoption of the DASH diet has been shown to reduce ambulatory blood pressure by -13.6/-9.5 mmHg as well as lowering blood glucose levels (51). A subsequent trial (the DASH-sodium trial) tested the effects of adherence to the DASH plus low sodium diet (52).

In the United States in 1999-2004, only 1 in 5 people with diagnosed hypertension ate a diet that was in accordance with DASH; people with diabetes had 1.53 times the odds of having a DASHadherent diet based on 24-hour food recall (53). In 2009, 61% of Canadians reported changing the types of food they eat (to include fruit and vegetables, lean fish or meat, and foods high in fibre and low in fat) all or most of the time to help control their blood pressure (47).

2.3.3.4 Weight control

Influenced by physical activity and diet, obesity is also a well-established risk factor for hypertension (28, 54) and weight loss is strongly associated with reduced blood pressure (55). For example, in a meta-analysis of 25 randomized controlled trials, Neter *et al.* showed that blood pressure was reduced by -1.0/-0.9 mmHg for each kg of weight loss, with larger reductions observed when weight loss exceeded 5 kg (55). Waist circumference, a measure of abdominal fat, correlates more strongly with systolic blood pressure in men and women and more strongly with diastolic blood pressure in men than body mass index (56). In Canada, clinical practice guidelines recommend that all overweight and obese people with hypertension be advised to lose weight and achieve a healthy body weight and waist circumference (body mass index 18.5-24.9 kg/m^2 and waist circumference < 102 cm for men and < 88 cm for women) (5).

In an analysis of the 2003 *Behavioral Risk Factor Surveillance System* in the United States, Zhao *et al.* showed that self-reported attempts at losing weight in people with hypertension varied by diabetes status, gender, and whether an individual was overweight or obese (57). Among men who were overweight, 49% of people with diabetes and hypertension reported attempting to lose weight compared to 39% with hypertension alone, after accounting for age. The same pattern was not observed among women who were overweight; instead, women with both diabetes and hypertension were less likely than those with hypertension alone to report trying lose weight

(55% vs. 61%). Among men and women who were obese, the proportion of people with both conditions trying to lose weight (81%) was higher than the proportion in people with hypertension alone (68% and 72% for men and women, respectively) (57). In that study, statistical testing of these differences was not performed, likely because these were not the main comparisons of interest. These estimates are much lower than those obtained from the 1998 *National Health Interview Survey* in the United States, which showed that, among Americans with hypertension, people with and without diabetes did not differ with respect to losing weight in response to advice from their doctor (92% vs. 87%; p<0.01) (49). In Canada in 2009, 54% of Canadians reported trying to control or lose weight all or most of the time to help control blood pressure (among those who reported being overweight or obese) (47). The extent to which Canadians with both hypertension and diabetes try to lose weight has not been described.

2.3.3.5 Sodium restriction

People with hypertension are recommended to restrict dietary sodium to 1500 mg per day if 50 years of age or younger, to 1300 mg per day if 51 to 70 years of age, and to 1200 mg per day if older than 70 years (5). The majority (77%) of dietary sodium comes from salt added to foods during processing, with the remaining 5%, 6%, and 11% added during cooking, added at the table, and naturally occurring in food (58). Half a teaspoon of salt is equivalent to 1200 mg of sodium (59). The top four sources of dietary sodium in the typical Canadian diet are breads, processed meats, pasta dishes, and cheese (60).

A recent Cochrane systematic review of 167 randomized controlled trials comparing low-sodium to high sodium diets showed that, in people with hypertension, low-sodium diet interventions resulted in a -5.5/-2.8 mmHg reduction in blood pressure among Caucasian people, a -6.4/-2.4 mmHg reduction in blood pressure among Black people, and a -10.2/-2.6 mmHg reduction among Asian people (61). A more recent meta-analysis restricted to trials lasting >4 weeks to <1 year showed that, in people with hypertension, modest salt reduction (-4.4 g/day) reduced blood pressure by -5.1/-2.7 mmHg in white people (17 trials), by -7.8/4.1 mmHg in black people (5 trials), and -5.4/-2.2 in Asian people (1 trial) (62). A third systematic review restricted to people with both diabetes and hypertension (13 trials), showed that lowered salt intake (-3.3 g/day) lowered blood pressure by -4.9/-3.0 mmHg (63).

North Americans, both with and without hypertension, consume sodium in much higher quantities than recommended. In the United States in 2003-2008, 99% of US adults with and without hypertension consumed more than the recommended 1500 mg/day with 91% consuming more than the tolerable upper intake level of 2300 mg/day (64), i.e., the level that can be consumed without resulting in known side effects. In 2004, the average sodium intake of Canadians with hypertension, based on self-reported 24-hour food recall, was 2767 mg/day in people with diabetes and 2987 mg/day in people without diabetes (65), amounts also well above the tolerable upper intake. This is in stark contrast to the 2009 study in which I found that 69% of Canadians reported limiting salt consumption all or most of the time for blood pressure control (47).

2.3.3.6 Alcohol restriction

To help control blood pressure, people with hypertension are also recommended to limit alcohol consumption to no more than 14 standard drinks per week for men or 9 standard drinks per week for women (5). In a meta-analysis of 7 randomized controlled trials, alcohol reduction in moderate-to-heavy drinkers with hypertension (66), of whom the vast majorities (95%-100%) were men, Xin *et al.* found that alcohol reduction ranging from 29% to 100% had a pooled effect of lowering blood pressure by -3.9/-2.4 mmHg in people with hypertension. In a more recent meta-analysis of 9 trials where alcohol was administered rather than reduced, McFadden *et al.* found that consumption of at least 1 alcoholic drink/day increased blood pressure by 2.7/1.4 mmHg; most of the participants in these trials were white or Asian men, with only 1 study including women (67). Neutel and Campbell showed that 8.6% of Canadians drank in excess of the guidelines prior to a diagnosis of hypertension, compared to 7.9% following diagnosis (46). In 2009, 43% of Canadians with hypertension reported limiting alcohol all or most of the time (among those who reported drinking in excess of the guidelines at any time since diagnosis) (47).

2.3.3.7 Stress management

Chronic psychosocial stress has been associated with incident hypertension in a number of longitudinal cohort studies (68); for example, in the CARDIA study (n=3,308) individuals with the highest time urgency/impatience scores and hostility scores at baseline had 1.8 (95% CI: 1.3-2.6) and 1.8 (95% CI: 1.3-2.5) times the odds of developing hypertension over 15 years, respectively, after adjusting for age, education, body mass index, physical activity, and alcohol consumption (69). In a systematic review of 17 randomized controlled trials, Rainforth *et al.* (68) found that blood pressure lowering effects differed according to the type of stress reduction strategy employed. In that meta-analysis, the only significantly effective stress management strategy was Transcendental Meditation (6 studies) which resulted in a -5.0/-2.8 mmHg decrease in blood pressure over a trial period of at least 8 weeks compared to attention-only controls (68).

Similarly, a separate meta-analysis of 9 trials found that Transcendental Meditation resulted in a pooled effect of -4.7/-3.2 mmHg (70). The trials included in these two systematic reviews were very small (ranging from 12 to 150 participants) (68), with only 4 restricted to people with hypertension (70). Current Canadian guidelines for the management of hypertension recommend that people with hypertension employ stress management strategies where applicable (5), without specifying the type of strategy that should be used. The extent to which Canadians with hypertension employ such methods has not, to my knowledge, been described and this gap is not addressed in the thesis.

2.3.3.8 Smoking cessation

The Canadian Hypertension Education Program recommendations do not specifically address smoking cessation. The C-CHANGE clinical practice recommendations for the prevention and treatment of cardiovascular disease, on the other hand, recommend that all health care practitioners strongly advise patients who smoke to quit and provide clear, unambiguous advice using a brief, personalized message (12), since smoking is an independent risk factor for cardiovascular disease (71, 72). Neutel and Campbell (46) showed that smoking cessation was the most commonly made behaviour change following a diagnosis of hypertension in Canadians: 27% of Canadians smoked before diagnosis compared to 22% following diagnosis (determined using the 1994-2002 longitudinal cycles of the *National Population Health Survey*). In 2009, 43% of Canadians with hypertension who had smoked since being diagnosed reported *not* smoking all of the time (68).

2.3.3.9 Multiple behaviour change

As just described, there are many things that people with hypertension can do to lower and control their blood pressure. Many of these behaviours are interrelated (such as physical activity/diet/weight control and diet/sodium) and engagement in multiple behaviours reduces blood pressure. The PREMIER randomized trial compared the blood pressure lowering effects of 1) multiple behaviour change (i.e., weight control, exercise, sodium reduction, and limited alcohol); 2) multiple behaviour change plus DASH diet and 3) advice-only, in 810 adults with prehypertension or stage 1 hypertension (73). Over the 6 month trial period, in participants with hypertension, blood pressure (measured using sphygmomanometry) decreased on average by -14.2/-7.4 mmHg, -12.5/-5.8 mmHg, and -7.8/-3.8 mmHg for each of the treatment arms respectively; decreases for the lifestyle modification arms were significantly greater than the advice-only treatment (73). In the PREMIER trial, only 45% of participants in the multiple behaviour change plus DASH diet intervention arm met 3 or more of the trial's behavioural goals at 6 months follow-up and only 8% met all 5 goals (of achieving ≥ 180 minutes of physical activity per week, consuming ≤ 100 mmol/day of sodium, consuming ≥ 2 daily servings of dairy, ≥ 9 daily servings of fruits and vegetables, and <24% of total daily calories from dietary fat) (74). At 18 months follow-up, adherence had decreased to 34% meeting 3+ goals and 3% meeting all 5 goals (74). These findings highlight the challenge of multiple behaviour change, particularly when we consider that these individuals, as participants in a trial, may have had greater motivation than would be otherwise observed in the general population (74). In Ontario in 2006, 42% of people with hypertension reported using lifestyle treatments (of diet, exercise, herbal remedies, and alcohol reduction) in combination with antihypertensive medications (75).

2.4 Review of studies examining relationship between physician advice, engagement in healthy lifestyle change, and blood pressure control

2.4.1 Physician advice for lifestyle behaviour change

Health care professionals may play an important role in addressing health behaviours that influence blood pressure (76), especially considering that two thirds of Canadians with hypertension report that they prefer to receive information and training on hypertension during medical appointments (77).

2.4.1.1 Efficacy of advice for multiple behaviour change

In a recent systematic review of 55 randomized controlled trials, counselling/education for multiple behaviour change was shown to lower risk of cardiovascular events (OR 0.78; 95% CI: 0.68-0.89) and lower blood pressure by -2.7/-2.1 mmHg over a median duration of 12 months (78). In keeping with this, the World Health Organization suggests that "moderately intense" primary care interventions, which include targeted information and follow-up, are effective in promoting adoption of healthy behaviours in those at risk for chronic disease (20). The United States Preventive Services Task Force has recommended that behavioural counseling in primary care use a 5A's approach; this involves **assessing** patient behaviour, knowledge beliefs and attitudes; **advising** using brief personalized messages that relate to symptoms, values, and concerns; **agreeing** on behavioural goals; **assisting** patients by providing counselling to develop an action plan; and **arranging** follow-up to assess progress (76).

2.4.1.2 Provision of advice in primary care

Provision of advice for lifestyle change in primary care may be suboptimal and may differ according to patient characteristics. Walker *et al.* showed that, in Canada in 2009, between 45% and 83% of Canadians with hypertension recalled receiving advice for limiting salt, eating a diet consistent with DASH, exercising, controlling or losing weight, quitting smoking, limiting alcohol consumption or reducing stress (79); these findings are consistent with other studies that have also shown low to moderate recall of provision of advice among people with hypertension (80-83). Canadians who were older than 65 years of age, those with less than a secondary school education, people living in rural areas, and people without a health care provider were less likely to report receiving any advice (79); the study did not consider the impact of diabetes. In the United States, one study found that younger adults were more likely to report receiving advice (84) whereas two studies have shown that advice is more often recalled by older adults (80, 82). In the United States, black people (81, 83, 85), men (83) and non-smokers (86) have also been shown to be more likely to receive advice for managing hypertension.

The above studies considered the advice *recalled* by patients and it is unclear to what extent and how health professionals provided advice. In a study of Dutch general practitioners, Frijling *et al.* (87) asked 195 physicians to complete a structured form directly after encounters with hypertensive patients (n=3659). During encounters where advice would be clinically relevant, 82% and 72% of newly diagnosed and treated hypertensive patients were reportedly advised to quit smoking respectively, 83% and 48% were advised to lose weight, 60% and 46% were advised to reduce salt consumption, and 33% and 31% were advised to limit alcohol (87). In another study of Dutch general practitioners, Milder *et al.* observed 212 video recordings of hypertension-related visits and found that general practitioners gave lifestyle advice in only 17% of visits (82). Although no study to my knowledge has described *provision* of advice by health professionals in Canada, ultimately it is the *recollection* of advice (i.e., that advice is provided, heard, and remembered) that likely influences behaviour change (88).

2.4.1.3 Provision of advice to people with and without diabetes

Only three studies have considered the influence of diabetes on receipt of behavioural advice for hypertension control and the findings are inconsistent. Windak *et al.* presented 8 case vignettes of hypertension to 125 Polish physicians and asked them to complete a questionnaire to measure competence in diagnosis, nonpharmacological treatment, and drug treatment (89). The investigators found that provision of advice for smoking cessation, sodium restriction, and increased fruit/vegetable consumption, and reduced fat intake was less likely in scenarios where the patient had diabetes, whereas advice for weight reduction and increased physical activity did not differ according to presence of diabetes (89). This is in contrast to findings from the 1998 *National Health Interview Survey* in the United States which showed that, among people with hypertension, individuals with diabetes were more likely than those without diabetes to recall receiving advice for weight loss (73% vs. 58%; $p<0.0001$) and physical activity (69% vs. 55%; $p<0.0001$) (49). Likewise, data from the 2005 *Behavioural Risk Factor Surveillance System* in the United States showed that people with diabetes were more likely to recall receiving advice for dietary change (74% vs. 59%, $p<0.001$), reducing salt intake (79% vs. 67%, $p<0.001$), exercise (89% vs. 77%, $p<0.001$) and reducing alcohol consumption (53% vs. 42%, $p=0.06$) (84).

2.4.1.4 Patient adherence to advice for behaviour change

Few studies have considered the extent to which people with hypertension follow the advice that they receive from health care professionals in population-based settings. Walker *et al.* showed that Canadians who recalled receiving advice for salt restriction, healthy diet, physical activity, weight loss, and limiting alcohol were 1.6 to 3.9 times more likely to report engaging in the respective behaviours all, most, or some of the time (77). Likewise, Viera *et al.* showed that Americans who recalled receiving advice for these behaviours were 1.3 to 1.8 times more likely to report engaging in the behaviours (90). Only one study, to my knowledge, has explored whether adherence to advice for health behaviours differs according to diabetes status. Egede showed that Americans with diabetes tended to report greater adherence to advice for weight loss (OR: 1.4; 95% CI: 0.91-2.15) but lower adherence to advice for physical activity (OR: 0.83; 95% CI: 0.62-1.12), although differences were not statistically significant (49). In these three studies, the use of self-reported measures may have biased the results if individuals who reported receiving advice from their health professional over-reported their engagement in response to a greater perceived social desirability. Furthermore, it is unclear to what extent these self-reported behaviours reflect current behaviours or changes over time.

2.4.2 Establishment of blood pressure targets

In addition to receiving advice, having a blood pressure target (or goal) may improve achievement of blood pressure control, as demonstrated by a few studies. In a clinic-based cross-sectional study of 197 Portuguese individuals with hypertension, Morgado *et al.* found that correct knowledge of systolic and diastolic blood pressure targets was associated with medication adherence (OR: 3.7; 95% CI: 1.9 to 7.4) and that medication adherence was associated with objectively-measured blood pressure control (OR: 4.8; 95% CI: 2.4 to 9.5) (91). In a cross-sectional clinic-based study (n=525), Knight *et al.* found that individuals who were not aware that systolic blood pressure should be less than 140 mmHg were significantly more likely to have uncontrolled blood pressure (OR: 1.6; 95% CI: 1.2-2.2) after controlling for age, gender, race, number of antihypertensive medications, and past experience of medication side effects (92). Participation rates in the study were low (38% to 49% across the three clinic sites) and it is unclear how patients were asked about target blood pressures. In another clinic-based cross-sectional study (n=188), Devore *et al.* showed that individuals with controlled blood pressure reported systolic blood pressure goals that were on average lower and closer to the actual target than individuals with uncontrolled blood pressure (93), without considering the effect of potential confounders. Both studies found that knowledge of the diastolic target was unrelated to having controlled blood pressure (91, 92). Finally, Wright-Nunes *et al.* (94) showed, in a sample of 338 adults with hypertension and chronic kidney disease, that systolic blood pressure was -10 mmHg lower in patients who could correctly identify the systolic blood pressure target, after adjusting for age, sex, race, stage of chronic kidney disease, and an assessment of health literacy; in that study 91% of participants reported that their blood pressure should be <130/80 mmHg.

Recent studies have shown that knowledge of recommended blood pressure targets in the United States is suboptimal with only 28% of individuals with hypertension having discussed and knowing the recommended target for systolic blood pressure and 39% having discussed and knowing the recommended target for diastolic blood pressure (95). Furthermore, knowledge of targets among individuals with chronic conditions is also low, with 50% of hypertensive individuals with coronary artery disease (96) and 60% of hypertensive individuals with diabetes knowing appropriate systolic and diastolic blood pressure targets (97). The extent to which Canadians with hypertension are aware of recommended blood pressure targets is currently unknown and examined in Chapter 5.

2.5 Measurement of blood pressure in epidemiologic studies

Studies of hypertension, such as those described above, make use of a number of methods for measuring blood pressure and blood pressure control. Common techniques for measuring blood pressure in epidemiologic research include office measurements (auscultatory and oscillometric methods) and out-of-office measurements (24-hour ambulatory monitoring and home blood pressure monitoring).

2.5.1 Office measurements

2.5.1.1 Auscultatory method

The auscultatory method involves using a manual sphygmomanometer and a stethoscope to determine systolic and diastolic blood pressure based on the Korotkoff sound method. In this method, the cuff of the sphygmomanometer is placed around the brachial artery. Cuff pressure is increased and slowly allowed to deflate until the Korotkoff sounds are audible by the person taking the measures through the stethoscope; phases of the Korotkoff sounds are used to determine systolic and diastolic blood pressure (98). The auscultatory method can induce the white-coat effect, which is the tendency for blood pressure to be elevated in the presence of an observer such as a doctor or nurse (98, 99). Observer errors, arising from differences in auditory acuity or digit preference, are also common (100). The latter is the tendency for observers to record a disproportionate number of readings ending in 5 or 0 (98). Cuff deflation rates, the cuff size, lack of calibration, the patient's arm position, and lack of arm support can also affect the accuracy and reliability of auscultatory measurements (100,101). Lack of accuracy has been hypothesized to be the cause of inconsistencies and bias in some trials of blood pressure control based on auscultatory readings (102).

2.5.1.2 Oscillometric methods

Oscillometric devices (i.e., automated blood pressure monitors) measure a person's mean blood pressure and apply proprietary device-specific algorithms to determine systolic and diastolic blood pressure (102). Numerous monitoring devices exist and each model is validated according to international protocols (102). The recent *Canadian Health Measures Survey*, a survey analyzed in this thesis, employed the BPTru automated blood pressure monitor (103). This device estimates systolic and diastolic blood pressure based on the average of five automated measurements. Blood pressure measurements obtained from BPTru correlate significantly better with 24-ambulatory blood pressures than clinic averages based on manual measurements (r=0.57 vs. r=0.14) (104). Compared to auscultatory methods, oscillometric devices have the advantage of ease of application and lack of reliance on an observer (102), thereby eliminating observer errors, digit preference, and reducing white-coat hypertension (105).

2.5.2 Out-of-office measurements

2.5.2.1 24-hour ambulatory monitoring

Ambulatory monitors allow blood pressure to be measured over 24 hours during normal day-to-day activities, with up to 100 measures recorded throughout the day. This type of measurement can provide three types of blood pressure information: the average blood pressure level, nocturnal blood pressure, and short-term variability (102). This method is therefore useful for assessing white-coat hypertension, masked hypertension (i.e., blood pressure that is controlled in the office but not at home) and effectiveness of medication (102). Prospective studies have demonstrated that 24 hour ambulatory blood pressure is a better predictor of cardiovascular risk (106-108). Furthermore, ambulatory blood pressure is an independent predictor of cardiovascular disease risk after accounting for manually-measured office blood pressure, as demonstrated in a 5-year prospective study of 1963 individuals treated for hypertension (109). The main disadvantage of this method is that it has a high cost relative to other available measures (102).

2.5.2.2 Home blood pressure monitoring

Home blood pressure monitoring is used increasingly to assess blood pressure (102). Like 24-hour ambulatory monitoring, this method is particularly useful for determining the presence of white-coat hypertension, masked hypertension, and monitoring the effectiveness of antihypertensive medications (102). Regular use of a validated, automated home blood pressure monitor is currently recommended for Canadians with diabetes, chronic kidney disease, suspected medication non-adherence, white-coat hypertension, and masked hypertension (5). To assess white-coat or sustained hypertension, patients are recommended to take 2 measurements in the morning and evening over 7 consecutive days (5). The use of memory-equipped automatic home blood pressure monitors are particularly useful in clinical trials of blood pressure lowering interventions to reduce reporting bias that may occur if participants exclude certain readings from their reports (102, 110).

2.5.3 Self-reported blood pressure

Self-reported blood pressure control has been used, albeit infrequently, in epidemiologic research. A few studies have evaluated the reliability of self-recorded blood pressures with those obtained electronically from home blood pressure monitors, with varying results (111-113). One study (sample size = 49) showed that self-recorded blood pressures were nearly identical to values recorded electronically over a six month period (111) whereas others have shown that individuals tend to underestimate their blood pressures (113) and that self-recorded systolic and diastolic blood pressure differed from electronic values by 10 mmHg or more in 20% and 17% of cases, respectively (sample size = 30) (112). The latter study also showed that erroneous reporting occurred more often among individuals with uncontrolled blood pressure compared to individuals with controlled blood pressure (112) whereas Mengden *et al.* (113) found no association between blood pressure control and reliability of self-recorded blood pressures. In these studies, because participants were not informed that the monitors recorded blood pressure readings, it is possible that participants experimented with the monitors or allowed other members of the household to use the monitors; participants would logically not have recorded such readings as their own and this may have biased estimates of accuracy. To date, no study has considered the accuracy of blood pressure control obtained through self-report on a questionnaire. This is an important gap given how blood pressure control has been monitored in Canada.

2.6 Measurement of blood pressure control in Canadian national surveys

In 2005, a committee was established by the Canadian Hypertension Society, the Canadian Coalition for High Blood Pressure Prevention and Control, and the Heart and Stroke Foundation to establish minimum standards for assessing blood pressure in surveys (114). The recommendations were that national surveys of hypertension awareness and control employ a validated automated oscillometric device that takes at least 3 readings per visit, in the absence of survey personnel or other observers, on 2 or more visits (114). Furthermore, in order to assess awareness and control, such surveys should include self-reported hypertension diagnosis (to assess awareness), self-reported use of antihypertensive medications, and lifestyle advice from a health professional to lower blood pressure. Based on these recommendations, the recent *Canadian Health Measures Survey*, a survey analyzed in this thesis, employed an automated oscillometric device to measure blood pressure based on 5 readings taken 1 minute apart in the absence of an observer on 1 visit (103).

In addition to the *Canadian Health Measures Survey*, the federal government also developed and fielded the hypertension component of the 2009 *Survey on Living with Chronic Diseases in Canada* (SLCDC), a survey designed partly to examine how Canadians with hypertension are managing their condition (115). The SLCDC asked Canadians with hypertension to report their perception of their blood pressure control. It was unclear to what extent self-reported blood pressure control reflects true rates of control, despite the fact that the national estimate of control based on self-report (77) agrees with the national estimate based on objectively measured blood pressure from a separate national survey (35). Understanding the validity of self-reported measures may allow researchers to address misclassification that would otherwise be unaccounted for in descriptive and etiologic studies.

2.7 Methods for addressing misclassification

Often in epidemiology, including hypertension research, measurement is not perfect, and as a result, a proportion of participants are often misclassified with respect to exposures, outcomes and/or covariates. For example, self-reported body mass index, a risk factor for hypertension, underestimates measured body mass index, since respondents tend to over-report their height and under-report their weight (116). Misclassification, such as this, can bias measures of association. Bias in the direction of no association (i.e., the null) can only be expected when misclassification is *exactly* non-differential (i.e., error probabilities are exactly the same between comparison groups), misclassification is independent of other errors, and the variable is naturally dichotomous (117-119). The direction of bias is less predictable when misclassification is only *approximately* non-differential, is dependent on errors in other variables, relates to a continuous or polytomous variable (even if dichotomized), or differs by comparison group (117-120). Traditionally, the effects of misclassification on measures of association have been addressed by back-calculating the two-by-two tables that would have been observed had the data been correctly classified (based on sensitivity and specificity) and, from these corrected tables, calculating a corrected odds ratio or relative risk (121). However, this method does not account for the increased uncertainty introduced by misclassification nor does it allow for multivariate analyses.

To address these limitations, bias analysis methods have been developed (122-125). One such method, developed by Fox and colleagues (125) uses ranges of sensitivity and specificity to recreate datasets that could have been observed had the individuals been correctly classified. An odds ratio is estimated from each reconstructed dataset to create a distribution of corrected odds ratios; the mean and the 2.5th and 97.5th percentiles give the odds ratio and a 95% confidence interval. While a few studies have demonstrated application of the method (126-128), to my knowledge no study has shown that the method can estimate the odds ratio based on 'true exposure' (thereby quantifying bias accurately) nor demonstrated the implications of improperly specifying misclassification parameters (such as assuming non-differential misclassification when differential misclassification exists) using real data.

2.8 Summary

In summary, evidence from a few studies suggests that people with diabetes may be less likely to have controlled blood pressure compared to people without diabetes. It is unclear whether this disparity generalizes to Canada as a whole, since this has not been described at the national level since 1992. In Chapter 3, I determine whether prevalence, awareness, treatment and control of hypertension differ between Canadians with and without diabetes in 2007-2009.

Although there is a considerable body of randomized controlled trial evidence supporting the efficacy of health behaviour change for blood pressure control, there is a paucity of evidence describing the extent to which people with hypertension actually engage in these recommended behaviours. In Chapter 3, I describe and compare health characteristics (such as body mass index and physical activity) in people with hypertension with and without diabetes. In Chapter 4, I compare self-reported engagement in health behaviours for blood pressure control and derive an index of multiple behaviour change.

Benefits of counselling and education for multiple behaviour change on reduced blood pressure have been demonstrated in a large number of randomized control trials. However, there are few studies that have addressed whether and how advice is provided in primary care settings and who recalls and follows such advice. In Chapter 4, I determine, among people with hypertension, whether 1) receipt of clinical advice for non-pharmacological management strategies and 2) engagement in these strategies, differ between Canadians with hypertension with and without diabetes. In Chapter 5, I describe the extent to which Canadians with hypertension have discussed a target blood pressure with a health professional and can recall the recommended blood pressure targets.

Finally, there are a number of methods for measuring blood pressure in epidemiologic studies. In the thesis, blood pressure was assessed using an automated blood pressure monitor, which has the advantage of reducing observer errors, digit preference, and white-coat hypertension. A self-reported measure of blood pressure control was recently included in a national survey of people with hypertension but it had never been validated. In Chapter 6, I determine the accuracy of this self-reported measure in a clinic-based patient population with hypertension. Recently, probabilistic sensitivity analysis methods have been developed that account for the effects of imperfect accuracy on measures of association; in Chapter 7, I demonstrate and test one such method in the context of commonly self-reported cardiovascular risk factors and their relationship to blood pressure control.

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Chapter 3

Prevalence, awareness, treatment and control of hypertension among Canadians with diabetes, 2007-2009

Abstract

Background: Prior national surveys suggested that treatment and control of hypertension were poor in individuals with diabetes. We estimated prevalence, awareness, treatment and control of hypertension among Canadians with diabetes using measured blood pressures in 2007-2009 and sought to determine if a treatment gap still exists for individuals with diabetes.

Methods: Using data from the 2007-2009 Canadian Health Measures Survey, estimates of hypertension prevalence, awareness, treatment, and control were described and compared between individuals with and without self-reported diabetes.

Results: Three quarters of individuals reporting diabetes also had hypertension; of these 89% (95% CI: 80%-98%) were aware, 88% (95% CI: 81%-94%) were treated and 56% (95% CI: 45%-66%) were controlled <130/80 mmHg. Among those treated with pharmacotherapy, 39% (95% CI: 31%-48%) were using monotherapy, 29% (95% CI: 18%-40%) were taking 2 medications, and 31% (95% CI: 22%-39%) were taking 3+ medications; control <130/80 mmHg was achieved by 63% (95% CI: 53%-74%). Among those treated, individuals with diabetes were significantly less likely to be treated to their recommended target (<130/80 mmHg) compared to individuals without diabetes (<140/90 mmHg) ($OR_{adjusted}$: 0.3; 95% CI: 0.2-0.6).

Conclusions: Hypertension treatment and control among people with diabetes has improved in Canada over the past 2 decades. Nonetheless, nearly half of people with diabetes are above the treatment target. Health care professionals should continue to increase their efforts in supporting

patients with diabetes in achieving blood pressure control, with emphasis on lifestyle management and pharmacotherapy.

Introduction

High blood pressure contributes substantially to morbidity and premature mortality among individuals with diabetes (1), accounting for up to 75% of stroke, 50% of kidney failure (2), 41% of cardiovascular events, and 44% of all deaths (3). Clinical practice guidelines recommend that people with diabetes and hypertension be treated to achieve blood pressures <130/80 mmHg using pharmacotherapy and lifestyle modification (4, 5). Despite the critical role of hypertension in adverse outcomes in diabetes, low rates of blood pressure control have been observed in the United States (30% <130/80 mmHg) and United Kingdom (42% <140/90 mmHg) (6, 7). Blood pressures have not been measured in a representative sample of Canadians since 1986-1992 (8).

In 1986 to 1992, treatment and control of hypertension was particularly poor in individuals with diabetes, with less than 10% of these individuals having treated blood pressures lower than 140/90 mmHg (8). Since that time, there has been a 46% increase in the population-adjusted rate of new antihypertensive prescriptions among elderly individuals with diabetes in the province of Ontario, from 13.9 new antihypertensive prescriptions per 1000 persons in 1995 to 20.3 new antihypertensive prescriptions per 1000 persons in 2001 (9). A recent study confirmed an improvement in the treatment and control of blood pressure among individuals with diabetes in Ontario, by demonstrating that, in 2006, 59% and 35% had their blood pressure controlled below 140/90 mmHg and 130/80 mmHg respectively (10). The study in Ontario found that individuals with diabetes were less likely to have their blood pressure controlled below 140/90 mmHg compared to individuals with other chronic conditions and individuals without these conditions

(10). Prompted by these findings, the Canadian Hypertension Education Program and the Canadian Diabetes Association, among others, called on health care professionals to redouble their efforts in helping patients with diabetes achieve appropriate blood pressure targets (11). It remains unclear, however, whether the findings in Ontario extend to the rest of Canada.

The current study describes the prevalence of hypertension among Canadian adults with diabetes in 2007-2009, and the proportions who are aware of the condition, receiving pharmacotherapy, and controlling their blood pressure. Furthermore, because two previous studies (10, 12) showed that people with diabetes were less likely to have their blood pressure controlled than those without diabetes, a secondary objective was to examine this relationship.

Methods

Study Population

Data from the 2007-2009 *Canadian Health Measures Survey* (CHMS) were analyzed. The CHMS is a household population survey, which excludes individuals living on First Nations reserves, Crown lands, in institutions and in certain remote regions, and full-time members of the regular Canadian Forces (13). The CHMS sampled respondents using a multistage cluster design, details of which are described in detail by Giroux (14). In brief, a total of 257 collection sites (geographic area with a population of at least 10,000 and a maximum respondent travel distance to the mobile clinic of 100 kilometres) were stratified according to region (British Columbia, Prairie provinces, Ontario, Quebec, Atlantic provinces) using the Labour Force Survey as the sampling frame; these cover 96.3 % of the Canadian population (14). These sites were sorted according to whether they belonged to a Census metropolitan area and population size. Fifteen sites were then sampled systematically with a probability of selection proportional to the size of their population, thus ensuring that selected sites would be distributed among census metropolitan and non-metropolitan areas and among areas with larger and smaller populations. Within each selected site, dwellings with known household composition at the time of the 2006 Census were stratified by age at the time of the survey; a simple random sample of dwellings was selected in each stratum. The selected dwellings were contacted to obtain a list of current household members, and from these one or two people were selected, depending on whether a child 6-11 years requiring accompaniment to the mobile examination centre was selected (14). Weights are applied that account for non-response and the demographic distribution of the 2006 Census population (13). The overall response rate was 52%, reflecting the household participation rate (70%), respondent participation rate (88%), and the proportion of respondents who attended the mobile clinic (85%) (13).

Blood pressures were available for 3515 adults aged 20 to 79 years ($n_{missing}$=2). Pregnant women (n=29) and individuals who answered "don't know", refused, or did not state an answer to the question "Do you have diabetes?" were excluded from the analysis (n=5), leaving 218 individuals with self-reported diabetes and 3263 individuals without diagnosed diabetes remaining for analysis. Type 1 and type 2 diabetes were not distinguished.

Data collection procedure

During the household interview, individuals were asked "Do you have high blood pressure [diagnosed by a health professional having lasted or expected to last six months or more]?" and "In the past month, have you taken medicine for high blood pressure?" On an appointed date after the interview, systolic and diastolic blood pressures were assessed using the BpTRU™ BP-300 device (BpTRU Medical Devices Ltd., Coquitlam, British Columbia) at the mobile clinic. In a quiet temperature controlled (21°C ± 2°C) room, participants were seated with back and arms supported and both feet on the floor. An appropriately sized cuff was chosen and fastened around the bare upper part of the right arm, with the center of the bladder over the brachial artery and lower margin of the cuff 2-3 cm above the antecubital fossa (elbow crease); the antecubital fossa was positioned at the apex of the heart with the palm of the hand facing down. Respondents were left alone and asked to sit quietly, relax and refrain from moving or talking for a five minute rest period. After the rest period, the health measures specialist re-entered the room to start the BPTru, remained in the room for the first measurement to ensure proper functioning, and left the room for the remaining five measurements (15). Average systolic and diastolic blood pressures were calculated from the last 5 of 6 blood pressure measurements taken one minute apart (15).

Key definitions

Hypertension. For individuals with diabetes, hypertension was defined as systolic blood pressure ≥130 mmHg or diastolic blood pressure ≥80 mmHg or the respondent's report of blood pressure medication use in the past month (4). For individuals without diabetes, hypertension was defined according to the 140/90 mmHg threshold (16).

Awareness of hypertension was defined as a respondent's self-report of either diagnosed high blood pressure or blood pressure medication use in the past month (16).

Treated hypertension was defined as a respondent's report of blood pressure medication use in the past month (16).

Controlled hypertension was defined as a respondent's report of blood pressure medication use in the past month together with a measured mean systolic blood pressure <130 mmHg and a mean diastolic blood pressure <80 mmHg (4). For comparisons between the population with and without diabetes and for comparison with previous studies, control was also defined using the 140/90 mmHg target.

Total number of antihypertensive medications was derived based on the Anatomical Therapeutic Chemical (ATC) Classification System codes of up to 15 prescription medications reported at the time of the household interview and up to 5 newly prescribed medications reported at the time of the clinic examination (13). Antihypertensive medications were those with ATC codes C02 (miscellaneous antihypertensive drugs – excluding Bosentan C02KX01), C03 (diuretics – excluding Metolazone C03BA08 and Furosemide C03CA01), C07 (beta blockers – excluding Sotolol C07AA07, Nadolol C07AA12, and Carvedilol C07AG02), C08 (calcium channel antagonists), C09-A, B (angiotensin converting enzyme inhibitors), C09-C, D (angiotensin receptor blockers), and C09-X (renin inhibitors).

Descriptive variables

The socio-demographic descriptors were: sex, age group, education, total household income, self-reported kidney disease/dysfunction (chronic kidney disease) or self-reported cardiovascular disease (heart disease, heart attack or stroke). Lifestyle descriptors were measured body mass index (BMI) (<25, 25-29, ≥30 kg/m^2), measured waist circumference (≥88 cm vs. <88 cm for women; ≥102 cm vs. <102 cm for men) (5), self-reported leisure-time physical activity (active, moderately active, inactive), and self-reported smoking status (current, former, never). The physical activity index was based on total daily energy expenditure calculated from self-reported frequency and duration of leisure-time physical activities (13).

Analysis

Data were analyzed using SAS Enterprise Guide version 4 (Cary, NC). Estimates were weighted to reflect the 2006 Canadian Census population aged 20 to 79 years. Differences according to presence of diabetes were quantified using odds ratios (OR) from logistic regression models, adjusting for sex, age (continuous), education, income, and presence of chronic kidney disease or cardiovascular disease. Standard errors (s.e.) and 95% confidence intervals (CI) around estimates were calculated using exact standard errors generated using bootstrap resampling methods following a t distribution with 11 degrees of freedom; the number of degrees of freedom reflects the number of primary sampling units (n=15) minus the number of sampling strata (n=4) (13, 17). In a sensitivity analysis, BpTRU measurements were adjusted to reflect sphygmomanometer readings (18), according to the validated equations: adjusted systolic blood pressure = 11.4 + (0.93 x BpTRU systolic) and adjusted diastolic blood pressure = 15.6 + (0.83 x BpTRU diastolic) (18).

Results

Characteristics of the study population

Five percent (95% CI: 4% to 6%) reported having diagnosed diabetes. Compared to individuals without diabetes, individuals with diabetes were typically older, had lower levels of education and income, and had higher BMI and waist circumference, and were more likely to report cardiovascular disease (Table 3-1).

Prevalence, awareness, treatment and control of hypertension among Canadians with diabetes

Three quarters (74%; 95% CI: 62% to 86%) of Canadian adults with diabetes had hypertension in 2007-09. Of these, 89% (95% CI: 80% to 98%) were aware of having the condition, 88% (95% CI: 81% to 94%) were treated with antihypertensive medication, and 56% (95% CI: 45% to 66%) were treated and controlled below 130/80 mmHg (Table 3-2). Among those treated, control <130/80 mmHg was achieved by 63% (95% CI: 53% to 74%) (Table 3-2). In the group with controlled blood pressure, average systolic blood pressure was 114.5 mmHg and average diastolic blood pressure was 66.9 mmHg. In the group with uncontrolled blood pressure (including those unaware, untreated, and treated but uncontrolled), average systolic blood pressure was 142.0 mmHg and average diastolic blood pressure was 78.5 mmHg; 81% (95% CI: 66% to 95%) had elevated systolic blood pressure and 61% (95% CI: 50% to 71%) had elevated diastolic blood pressure.

The mean number of antihypertensive medications reported among those treated was 2.0 ± 0.08 (Table 3-2) and 31% (95% CI: 22% to 39%) were taking 3+ medications. Self-reported medication use in the previous month showed good agreement with the medications inventory, with 96% sensitivity and 92% specificity.

Comparison between individuals with and without diabetes

Prevalence of hypertension was 4 times higher among individuals with diabetes than among individuals without diabetes (74% vs. 17%, p<0.0001) (Table 3-1). Even if the 140/90 mmHg cutoff was used to define hypertension, the prevalence was still markedly higher in individuals with diabetes (69% vs. 17%, p<0.0001). Individuals with diabetes and hypertension were slightly more likely than those with hypertension alone to be aware of having hypertension (89% vs. 81%, p=0.08) (Table 3-2).

Although little difference was observed in the proportion treated, people with diabetes took, on average, a slightly greater number of antihypertensive medications (2.0 vs. 1.7, p=0.008) (Table 3-2). Individuals with diabetes were equally likely to be taking 1 medication (39% vs. 40%, p=0.8), less likely to be taking 2 medications (29% vs. 42%, p=0.02), and more likely to be taking 3+ medications (31% vs. 15%, p=0.004). Among those aware, individuals with diabetes were less likely to have a BMI <25 kg/m^2 (13% vs. 22%, p=0.02), to have a waist circumference <88 cm (women) or <102 cm (men) (28% vs. 43%, p=0.005), and to report being physically active (11% vs. 20%, p= 0.02) than individuals with hypertension alone. Differences remained after adjustment for age, sex, income, education, and presence of cardiovascular disease or chronic kidney disease.

Among those treated, the proportion who were controlled below 140/90 mmHg did not differ according to diabetes status (Table 3-2). Among those treated, individuals with diabetes were significantly less likely to be treated to their recommended target compared to individuals without diabetes (63% <130/80 mmHg vs. 83% < 140/90 mmHg), after adjusting for age, gender, income, education, and presence cardiovascular disease or chronic kidney disease ($OR_{adjusted}$: 0.3; 95% CI: 0.2-0.6). The sensitivity analyses using adjusted blood pressures showed similar results (Appendix A).

Correlates of blood pressure control among those with diabetes

Hypertension prevalence, awareness, and control among individuals with diabetes is described according to demographic and lifestyle characteristics in Table 3-3. Although associations between presence of hypertension, awareness and control and individual characteristics were observed in the expected directions, these did not reach statistical significance; differences ranged from 9% to 17% for awareness and 4% to 21% for control.

Discussion

This study found that, of the three quarters of Canadians with diabetes who also have hypertension, just over half had their blood pressure controlled to target in 2007-2009. The rate of hypertension control in Canadians with diabetes is almost twofold higher than control rates reported in the United Kingdom (7) and the United States (6), and is much higher than that observed in Canada in 1986-1992. Small reductions in blood pressure (6/4.6 mmHg) in persons with diabetes have been associated with a 27% reduction in total mortality and 25% reduction in total cardiovascular events (19); hence, the high rates of blood pressure control in Canadians with diabetes has undoubtedly had a positive impact on their cardiovascular health.

The much improved rate of control in Canada, from <10% below 140/90 mmHg in 1986-1992 to 56% below 130/80 mmHg in 2007-2009, is consistent with previous findings in Ontario (10). These improvements may be attributable, in part, to improved antihypertensive medications with fewer side-effects and secular improvements in the clinical management of hypertension, recommended by the Canadian Hypertension Education Program initiative and its partnerships with the Heart and Stroke Foundation, the Canadian Diabetes Association, and the Public Health Agency of Canada (20). In 1999, the Canadian Hypertension Education Program launched an extensive education program to improve blood pressure control in Canada and in 2008 refocused the program to emphasize blood pressure control in people with diabetes (11), based on the preliminary results from a blood pressure survey from Ontario (10). This initiative included the development of a large number of resources and their dissemination to health care professionals and people with diabetes (available at www.hypertension.ca).

In contrast to previous findings (10, 12), a disparity in control was not observed between individuals with and without diabetes at the 140/90 mmHg threshold. However, fewer individuals with diabetes were controlled to their recommended target (63% <130/80 mmHg) relative to those without diabetes (83% <140/90mmHg). Furthermore, although individuals with diabetes were taking more antihypertensive medications on average, they were less likely to have lifestyles that would aid in blood pressure control.

Whether individuals with diabetes should be treated to a 130/80 mmHg target is an important question. The recent ACCORD trial showed that systolic blood pressure control <120 mmHg did not confer overall benefit in terms overall cardiovascular events, but did confer benefit in terms of stroke incidence (hazard ratio, 0.59; 95% CI, 0.39 to 0.89) (21). Furthermore in the group randomized to routine glycemic control, those further randomized to the lower blood pressure appeared to have a statistically significant reduction in cardiovascular events (supplementary appendix of Cushman *et al.* (21)). However, the study concluded that control <120 mmHg was not beneficial and has raised questions about current recommendations (22, 23). A recent meta-analysis of 73,913 people with diabetes found that tight control of blood pressure reduced the risk of stroke, with risk decreasing by 13% for every 5 mmHg reduction in systolic blood pressure and by 12% for each 2 mmHg reduction in diastolic blood pressure (24). Given the current debate around blood pressure targets for people with diabetes, we evaluated control based on Canadian clinical practice guidelines at the time of the survey (blood pressure <130/80 mmHg) and also considered the 140/90 mmHg target in order to compare with previous studies in Ontario (10) and the United States (6).

The current study is strengthened by objectively measured blood pressure in a nationally representative sample of Canadians but limited by the small sample size. We expect that the prevalence of controlled blood pressure (<130/80 mmHg) in those with diabetes would be estimated between 45% and 66%, 19 times out of 20, based on the sample size of 218. With future cycles of the CHMS, these findings can be confirmed, with changes assessed over time. Furthermore, because of the small sample and design of the CHMS, the analysis was underpowered to detect differences according to demographic characteristics in the subsample with diabetes; thus, we could not address ethnic or vulnerable populations, nor produce provincial estimates. Second, estimates may be conservative since participants in surveys are often healthier than the general population. For example, the prevalence of diabetes in the CHMS (5%) was slightly lower than that estimated using Canadian hospitalization and physician billing data (6%) (25). It does not appear that presentation to the clinic imposed a further selection pressure; individuals who did and did not attend the clinic were similar in terms of self-reported BMI, health utility index scores, access to a regular medical doctor, and use of medications (13). Another limitation of the survey is that it did not include questions about lifestyle therapy for blood pressure control. As a result it was not possible to determine whether the small number (n=51) of CHMS participants who reported a diagnosis of hypertension but who were not taking medication and had normal measured blood pressures were controlling their blood pressure with lifestyle changes alone or were truly non-hypertensive.

Concern has been expressed previously that the methods used to assess blood pressure in the CHMS may have inflated the rates of hypertension awareness and control as compared to other countries (26). Although some differences may be due to the measurement technique employed, this is expected to be minimal and unlikely to have affected the observed relationships. The Ontario Blood Pressure survey employed the same fully automated blood pressure assessment method used in the CHMS, but also employed a single auscultatory measurement using a mercury sphygmomanometer in 10% of the survey sample. The fully automated readings were 1.6/0.3 mmHg lower than manual readings at the therapeutic cut-point of 140/90 mmHg (18). When the calibration equation from the Ontario study (18) is applied to the CHMS data, the proportions controlled <130/80 mmHg and <140/90 mmHg decrease to 46% (95% CI: ± 7%) and 67% (95%CI: ± 8%), respectively (see Appendix A). These estimates are still higher than those observed in the United States in 2004 (30% ± 5% <130/80 mmHg based on sphygmomanometry (6)) and United Kingdom in 2006 (42% ± 6% <140/90 mmHg based on the Omron automated device (7) - note: we estimated the standard error for the United Kingdom estimate assuming simple random sampling, as it was not presented by Falaschetti *et al.* The non-overlapping 95% confidence intervals of the estimates suggest that control rates in Canada are higher and that these differences are unlikely to have resulted entirely from the measurement technique employed.

Canada may have the highest rates of hypertension treatment and control in the world, and may be a standard of care for other countries to follow. Nonetheless, nearly half of all people with diabetes are above the hypertension treatment target. Health care professionals should continue to increase their efforts in supporting patients with diabetes in achieving blood pressure control, with emphasis on lifestyle management and pharmacotherapy. With future cycles of the ongoing CHMS, the current findings can be confirmed and changes over time can be assessed.

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Table 3-1. Characteristics of the study population, household population aged 20-79 years, Canada 2007-2009.

	With diabetes (n=218)		Without diabetes (n=3253)	
	N	**%** (95% CI)	N	**%** (95% CI)
Has hypertension	169	74.2 (62.4, 86.0)	705	17.0 (15.1, 18.8)
Systolic blood pressure (mean ± s.e).		122.5 ± 3.0 mmHg		112.8 ± 0.6 mmHg
Diastolic blood pressure (mean ± s.e).		71.1 ± 1.0 mmHg		72.4 ± 0.4 mmHg
Sex				
Female	106	49.8 (39.9, 59.6)	1727	50.1 (49.6, 50.6)
Male	112	50.2 (40.3, 60.1)	1536	49.9 (49.4, 50.4)
Age				
20-39	14	4.5 (1.5, 7.5) E	1144	39.3 (38.8, 39.8)
40-59	50	35.9 (28.3, 43.5)	1178	41.7 (41.3, 42.2)
60-79	154	59.6 (51.8, 67.4)	941	18.9 (18.5, 19.4)
Mean ± s.e.		59.8 ± 1.0 years		44.8 ± 0.1 years
Ethnicity				
White	183	82.4 (72.0, 92.9)	2777	82.3 (74.4, 90.3)
Non-white	35	17.6 (7.1, 28.0)	481	17.7 (9.7, 25.6)
Highest level of education				
Less than secondary	67	36.0 (29.5, 42.5)	400	11.1 (8.3, 13.9)
Secondary graduate	37	17.8 (11.7, 24.0)	538	18.5 (13.9, 23.1)
Some post-secondary/Post-secondary graduate	113	46.1 (40.0, 52.2)	2287	70.4 (63.6, 77.3)
Total Household Income				
≤ $29,999	69	29.9 (20.4, 39.4)	549	14.2 (10.9, 17.5)
$30,000-$49,999	65	26.5 (15.0, 38.0) [E]	638	18.5 (16.5, 20.5)
$50,000-$79,999	39	18.5 (12.6, 24.3)	773	26.2 (23.2, 29.1)
≥ $80,000	36	25.1 (18.8, 31.5)	1127	41.1 (36.2, 46.1)

	With diabetes (n=218)		Without diabetes (n=3253)	
	N	**%** (95% CI)	N	**%** (95% CI)
Comorbidities				
Heart disease, heart attack or stroke	53	22.0 (13.2, 30.8) E	222	5.8 (4.5, 7.1)
Kidney dysfunction or disease	15	5.1 (1.4, 8.8) E	53	1.4 (0.8, 1.9) E
Body mass index				
Normal (BMI <25 kg/m^2)	36	18.5 (9.7, 27.2) E	1220	39.2 (33.6, 44.9)
Overweight (BMI 25-29 kg/m^2)	70	35.8 (29.9, 41.6)	1252	37.4 (33.6, 41.2)
Obese (BMI≥ 30 kg/m^2)	111	45.8 (36.9, 54.6)	785	23.4 (19.9, 26.8)
Mean ± s.e.		30.4 ± 0.5 kg/m^2		27.0 ± 0.2 kg/m^2
Waist circumference				
<88 cm for women; <102 cm for men	61	36.2 (24.4, 48.1)	2030	64.7 (59.9, 69.6)
≥88 cm for women; ≥102 cm for men	157	63.8 (51.9, 75.6)	1233	35.3 (30.4, 40.1)
Leisure-Time Physical activity				
Active	34	12.6 (6.9, 18.4) E	680	20.9 (16.9, 24.9)
Moderately active	51	22.3 (13.6, 31.0 E	844	24.5 (21.4, 27.6)
Inactive	133	65.1 (55.0, 75.2) E	1739	54.5 (47.8, 61.2)
Smoking status				
Never smoker	97	41.8 (31.6, 51.9)	1555	48.3 (45.0, 51.5)
Former smoker	87	39.0 (28.2, 49.9)	1028	30.1 (26.9, 33.2)
Current smoker– daily or occasional	32	19.2 (7.9, 30.5) E	673	21.7 (19.6, 23.8)

E interpret with caution (coefficient of variation 16.6% to 33.3%

Table 3-2. Among those with hypertension, proportion aware, treated, and controlled by diabetes status, household population aged 20-79 years, Canada 2007-2009.

	With Diabetes (n=169)		Without Diabetes (n=705) Referent		Crude Odds Ratio		Adjusted† Odds Ratio	
	N	**% (95% CI)**	**N**	**% (95% CI)**	**OR**	**(95% CI)**	**OR**	**(95% CI)**
Total hypertensive* population	**169**		**705**					
Aware	155	88.9 (79.7, 98.1)	549	81.1 (75.6, 86.6)	1.9	(0.5, 7.2)	1.3	(0.3, 4.9)
Treated	153	87.7 (81.1, 94.4)	522	77.0 (71.2, 82.8)	2.1	(0.9, 5.1)	1.4	(0.6, 3.6)
Controlled <140/90	126	71.6 (60.4, 82.7)	420	63.6 (58.2, 69.0)	1.4	(0.8, 2.7)	1.1	(0.6, 2.1)
Controlled <130/80	98	55.5 (45.3, 65.6)	276	39.1 (32.8, 45.4)	**1.9**	**(1.2, 3.1)**	1.4	(0.9, 2.3)
Among those aware	**155**		**549**					
Treated with medication	153	98.7 (95.2, 100)	522	94.9 (92.0, 97.8)	‡		‡	
Lifestyle management								
BMI < 25 kg/m^2	14	13.1 (1.4, 24.8) [E]	113	21.9 (14.0, 29.8)	0.5	(0.1, 1.8)	0.5	(0.1, 2.4)
Waist circumference <88 cm for women; <102 cm for men	32	27.6 (15.5, 39.6) [E]	232	43.2 (35.3, 51.0)	**0.5**	**(0.3, 0.8)**	**0.4**	**(0.3, 0.7)**
Physically active	21	11.0 (6.0, 16.0) [E]	109	20.3 (14.4, 26.1)	**0.5**	**(0.2, 0.9)**	**0.5**	**(0.3, 1.0)**

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	With Diabetes (n=169)		Without Diabetes (n=705) Referent		Crude Odds Ratio		Adjusted† Odds Ratio	
	N	% (95% CI)	N	% (95% CI)	OR	(95% CI)	OR	(95% CI)
Among those treated	**153**		**522**					
Controlled <140/90 mmHg	126	81.5 (73.9, 89.2)	420	82.7 (77.3, 88.0)	0.9	(0.6, 1.5)	1.0	(0.6, 1.4)
Controlled <130/80 mmHg	98	63.2 (52.7, 73.8)	276	50.8 (42.9, 58.8)	**1.7**	**(1.0, 2.7)**	1.4	(0.8, 2.4)
Number of antihypertensive medications								
1	53	39.4 (31.3, 47.5)	214	40.4 (32.5, 48.3)	0.9	(0.6, 1.3)	1.1	(0.6, 1.9)
2	48	29.2 (17.7, 39.6)	192	42.4 (35.4, 49.3)	**0.6**	**(0.4, 0.9)**	**0.6**	**(0.3, 0.9)**
3+	48	30.8 (21.5, 39.0)	105	14.5 (10.8, 18.3)	**2.5**	**(1.5, 4.3)**	**2.2**	**(1.1, 4.4)**
Missing=15								
		Mean ± s.e.		**Mean ± s.e.**	**Δ**	**(95% CI)**		
Number of antihypertensive medications		2.0 ± 0.08		1.7 ± 0.05	**0.4**	**(0.1, 0.6)**		

† adjusted for: sex, age (continuous), education, income, chronic kidney disease or cardiovascular disease

‡ not estimable

Significant ORs and differences are in **bold**

Table 3-3. Among individuals with diabetes, proportion with hypertension, aware, treated and controlled by sociodemographic and lifestyle characteristics, Canada 2007-2009.

	% with hypertension*		Among those with hypertension (n=169), % aware		Among those treated (n=153), % controlled <130/80 mmHg	
	N	**%** (95% CI)	N	**%** (95% CI)	N	**%** (95% CI)
Sex						
Female	81	71.2 (52.3, 90.0)	76	95.2 (90.0, 100)	48	65.6 (52.9, 78.3)
Male	88	77.2 (63.6, 90.9)	79	83.1 (64.3, 100)	50	61.0 (42.6, 79.4)
Age						
20-39	F	F	F	F	F	F
40-59	36	68.2 (42.4, 94.0)[E]	32	78.3 (52.8, 100)	20	68.3 (46.1, 90.6)
60-79	128	81.9 (72.2, 91.5)	119	94.6 (91.7, 97.5)	76	61.7 (51.2, 72.1)
Highest level of education						
Less than secondary	58	81.6 (63.5, 99.7)	55	97.0 (92.6, 100)	35	60.6 (44.9, 76.3)
Secondary graduate	25	61.5 (33.9, 89.2) [E]	24	93.4 (80.8, 100)	16	66.5 (41.8, 91.3)[E]
Some post-secondary/Post-secondary graduate	85	73.3 (62.5, 84.1)	75	80.3 (60.1, 100)	47	65.3 (52.0, 78.6)
Income						
≤ $29,999	52	73.7 (55.1, 92.3)	48	94.8 (89.4, 100)	24	45.0 (24.8, 67.1) [E]
$30,000-$49,999	56	84.7 (75.7, 93.7)	50	86.9 (78.0, 95.8)	33	60.2 (41.4, 79.0)
$50,000-$79,999	27	60.0 (43.9, 76.2)	24	91.0 (78.8, 100)	17	80.2 (66.3, 94.1)
≥ $80,000	25	68.2 (42.9, 93.4)	24	78.6 (41.8, 100)[E]	16	66.4 (32.5, 100) [E]
Cardiovascular disease or chronic kidney disease						
No	119	72.4 (56.6, 88.1)	105	85.0 (73.4, 96.5)	63	62.0 (51.3, 72.8)
Yes	50	80.0 (66.3, 93.8)	50	100 (not estimable)	35	66.1 (48.6, 83.6)

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BMI

	% with hypertension*		Among those with hypertension (n=169), % aware		Among those treated (n=153), % controlled <130/80 mmHg	
	N	**%** (95% CI)	N	**%** (95% CI)	N	**%** (95% CI)
<25 kg/m^2	20	57.6 (24.4, 90.8) [E]	14	81.8 (68.2, 95.5)	F	F
25-29 kg/m^2	56	73.1 (55.3, 90.9)	53	82.9 (61.4, 100)	35	63.4 (48.8, 78.0)
≥ 30 kg/m^2	93	82.9 (72.5, 93.3)	88	95.0 (89.5, 100)	56	65.2 (46.9, 83.4)
Waist circumference						
<88 cm for women; <102 cm for men	40	67.4 (46.7, 87.8)	32	74.5 (54.1, 94.9)	20	58.6 (38.8, 78.3)
≥88 cm for women; ≥102 cm for men	129	78.1 (66.8, 89.5)	123	95.9 (92.5, 99.4)	78	65.0 (53.5, 76.6)
Physical activity						
Active	24	64.5 (52.0, 76.9)	21	89.1 (74.0, 100)	13	52.4 (28.1, 76.7) [E]
Moderately active	43	76.8 (57.6, 96.0)	40	92.3 (82.3, 100)	27	66.6 (56.6, 76.6)
Inactive	102	75.3 (61.2, 89.3)	94	87.7 (72.6, 100)	58	63.8 (45.6, 82.1)
Smoking status						
Never smoker	71	77.2 (66.9, 87.4)	64	82.9 (62.1, 100)	42	65.5 (47.7, 83.3)
Former smoker	73	77.9 (63.1, 92.6)	69	95.7 (90.2, 100)	44	64.3 (51.8, 76.9)
Current smoker	23	59.2 (30.0, 88.4)	20	86.8 (69.7, 100)	10	50.3 (21.4, 79.3) [E]
Number of antihypertensive medications						
1		n.a.		n.a.	35	73.2 (57.8, 88.6)
2		n.a.		n.a.	30	53.8 (53.8, 82.6)
3+		n.a.		n.a.	29	57.2 (38.9, 75.4)

[E] interpret with caution (coefficient of variation 16.6% to 33.3%)

[F] too unreliable to be reported (coefficient of variation greater than 33.3%)

Chapter 4

Health behaviours for hypertension management in people with and without coexisting diabetes

Abstract

Since blood pressure control is less often achieved by individuals with diabetes, we sought to determine whether receipt of and adherence to health behaviour advice for hypertension control differs between people with and without diabetes, using data from the 2009 Survey on Living with Chronic Diseases in Canada. Individuals with coexisting diabetes were more likely to report receiving advice to control/lose weight (81% vs. 66%), be physically active (79% vs. 68%), limit alcohol consumption (78% vs. 55%) and modify diet (70% vs. 61%) but not limit dietary salt (65% vs. 64%) compared to individuals with hypertension alone (n=4,965). People with and without diabetes were equally likely to report following the advice they received, with receipt of advice positively associated with engagement in healthy behaviours. Since receipt of advice appears to influence behaviour, health professionals should be encouraged to further promote blood pressure self-management strategies.

Introduction

Elevated blood pressure is an important risk factor for cardiovascular disease among individuals with diabetes, accounting for up to 44% of deaths and 41% of cardiovascular disease events in this group (1). Although blood pressure control among people with coexisting diabetes has improved in recent years (2-4), individuals with diabetes are still less likely to have their blood pressure controlled (<130/80 mmHg) relative to individuals without diabetes (<140/90 mmHg)

(5-7). In Canada, blood pressure control is similar between the two groups when control is defined based on a <140/90 mmHg threshold (7). Furthermore, although individuals with diabetes take more antihypertensive medications on average, they are more likely to have other risk factors for poor blood pressure control (e.g. unhealthy body weight and being physically inactive) (7).

In order to manage blood pressure, clinical practice guidelines recommend that individuals with hypertension: 1) reduce dietary salt to 1500 mg/day or less depending on age; 2) eat a healthy diet; 3) limit alcohol consumption; 4) participate in aerobic exercise; 5) attain or maintain a healthy body weight and 6) use stress management strategies where needed (8,9). Many of these behaviours are also indicated for management of diabetes (10). People who are advised by their health professional to make these changes may be more likely to do so (11, 12). Understanding the extent to which healthy behaviours are recommended by clinicians and followed by individuals with both diabetes and hypertension may identify areas for intervention to reduce previously observed disparities in blood pressure control.

Using a large population-based survey of people with hypertension, we sought to determine whether 1) receipt of clinical advice for non-pharmacological management strategies and 2) engagement in these strategies differ between individuals with and without diabetes. Furthermore, we sought to determine whether likelihood of following advice differed by diabetes status, as well as by gender, level of education, and time since diagnosis.

Methods

Data source

The 2009 *Survey on Living with Chronic Disease in Canada* (SLCDC) Hypertension Component is a cross-sectional survey that collected information related to the experiences of Canadians with hypertension. Details surrounding the survey objectives, questionnaire development, sampling frame, and associated methodology are reported in detail elsewhere (13, 14). In brief, the questionnaire was developed by a panel of hypertension and survey development experts assembled by the Public Health Agency of Canada; survey questions were identified from publicly available population surveys and peer-reviewed instruments and scales, with some survey questions modified to reflect national hypertension guidelines (14).

Adults ages 20 years and older, living in the 10 Canadian provinces, and who reported having been diagnosed with high blood pressure (n=7,862) were selected from the 2008 *Canadian Community Health Survey*. Of these, 6,142 individuals (representing approximately 5 million Canadians) agreed to participate, for a response rate of 78.2% (13). Excluded from the *Canadian Community Health Survey*, and subsequently from the 2009 SLCDC, were full-time members of the Canadian Forces, persons living on Indian reserves or Crown lands, and residents of institutions or of certain remote regions; together these exclusions are estimated to represent <2% of the population (13). Residents of the three northern territories were excluded from the SLCDC due to insufficient sample sizes which would lead to an inability to properly weight findings to represent all residents of the territories (14).

Computer-assisted telephone interviews were conducted between February and April 2009. Data from the SLCDC were linked to data from the 2008 *Canadian Community Health Survey* (collected between January and December 2008.) The latter provided information on household income, education, marital status, race/ethnicity, body mass index (BMI – based on self-reported height and weight), and diabetes status. Individuals who reported having previous gestational diabetes only (n=2) were classified as not having diabetes. Individuals who answered "do not know" (n=7) were excluded, leaving 1,170 and 4,965 individuals with and without diabetes, respectively.

Clinical recommendations for self-management

Participants were asked about advice ever received (yes/no) from health professionals for blood pressure control including: limiting salt intake, eating certain foods (such as fruits and vegetables, fish or lean meats, foods high in fiber or foods low in fat), engaging in physical activity, maintaining or losing weight, cutting down on smoking, limiting alcohol consumption, reducing stress levels, and correct use of a home blood pressure monitor.

A composite measure of receipt of clinical advice for self-management was derived by summing positive responses for advice received for salt restriction, dietary changes, weight control/weight loss, and physical activity, based on the results of factor analysis of categorical data (i.e. latent trait analysis) which showed that these factors comprise a single domain (Appendix B) and that advice for medication use and self-monitoring of blood pressure did not fit well within this domain. These variables had reasonable internal consistency (Cronbach's alpha=0.73)

Self-management of high blood pressure

Participants were asked if, as a result of being diagnosed with high blood pressure, they ever: 1) limited their daily salt intake, 2) changed the types of food they eat (choosing more fruits and vegetables, fish or lean meats, foods high in fiber or foods low in fat), 3) exercised or participated in physical activities, and 4) tried to control or lose weight; the latter was described among individuals who were overweight or obese (i.e. BMI $\geq$25 kg/m^2 based on self-reported height and weight). Those who reported smoking at any time since their hypertension diagnosis were asked if they ever quit or cut down on smoking to help control their blood pressure. Respondents who reported regularly drinking more alcohol than recommended (i.e. >14 drinks of alcohol for men or >9 drinks of alcohol for women per week) since their diagnosis were asked if they ever limited their alcohol consumption to help control their blood pressure.

For each behaviour, individuals who answered “yes” to ever engaging in the activity were asked if they continued to maintain the change “all of the time”, “most of the time”, “some of the time” or “none of the time”. Those who indicated having never engaged or no longer engaging in a respective behaviour were asked the open ended question “What are the reasons that you are not [engaging in the behaviour] to help control your blood pressure?”. A substantial number of respondents reported not engaging in behaviours for blood pressure control because they were already doing so “for other reasons” and were categorized as a separate group.

In order to correspond to the composite measure of clinical advice, an overall healthy behaviour score was derived by summing ordinal responses for salt restriction, dietary changes, weight control/weight loss, and physical activity (with each variable given a score of 0=“none of the time”; 1= “for other reasons”; 2= “some of the time”; 3= “most of the time” and 4= “all of the time”). Latent trait analysis revealed agreement between these 4 behaviours (Appendix B; Cronbach’s alpha=0.64). The possible range for the derived score was 0 (does not engage in any of the four behaviours) to 16 (engages in all four behaviours all of the time).

Participants were asked about monitoring their own blood pressure outside of a health professional’s office or medical clinic. Specifically, respondents were asked whether (yes/no), how often (daily, weekly, monthly, 3-4 times a year, once a year, less than once a year, never), and where (home, pharmacy, workplace, gym/fitness facility, other) they measure their blood pressure. Regular use of home blood pressure monitoring was defined as measuring one’s blood pressure at home at least weekly.

Statistical Analysis

Data were analyzed using SAS Enterprise Guide 4.1 (Cary, North Carolina). Point estimates were weighted to reflect the Canadian household population (13). The 95% confidence intervals (CI) were calculated using exact standard errors obtained using bootstrap re-sampling methods (15). Latent trait analysis (i.e. factor analysis of binary or ordinal data) was used to develop the clinical advice score and the healthy behaviour score (http://support.sas.com/kb/22/558.html).

Socio-demographic characteristics were compared between individuals with and without diabetes using chi-square (χ^2) tests of association based on a weighted bootstrap procedure. The association between diabetes status and 1) receipt of advice for self-management behaviours and 2) engagement in self-management behaviours all/most of the time were evaluated using crude and multivariate prevalence ratios (PRs) estimated using log-binomial regression. Potential confounders (gender, age group, ethnicity, education, total household income, marital status, region, time since diagnosis were identified *a priori* based on previous descriptive analyses of the 2009 SLCDC (16-18); covariates were retained if their exclusion caused a ≥5% change in the primary effect estimate observed from fully adjusted models (19). Number of consultations with health professionals in the previous year was not considered as a potential confounder as it would lie on the causal pathway between diabetes status and receipt of advice, since diagnosis of diabetes may result in more referral care and thus more opportunity to receive advice.

In order to determine whether receipt of clinical advice for blood pressure control is associated with engagement in self-management behaviours to the same or different extent among people with and without diabetes, we modeled the relationship between the clinical advice score and the healthy behaviour score in a linear regression model that included an interaction term between diabetes status and clinical advice.

Results

Sample characteristics and comparison of individuals with and without diabetes

One in five (19%) people with hypertension reported having coexisting diabetes. The average age of the sample was 62 years with an even split of men and women (Table 4-1). Reflecting this population in Canada, the majority were white (87%), relatively affluent (54% ≥ household income $50,000), married (68%), urban-dwelling (86%), educated (52% with post-secondary education) adults. The majority (63%) had been diagnosed with hypertension more than 5 years before the survey.

As shown in Table 4-1, compared to individuals without diabetes, those with diabetes were older and had lower household income. Individuals with diabetes were also more likely to have been diagnosed with hypertension 10 or more years ago (42% vs. 57%, $p=0.0003$). The majority of individuals with and without coexisting diabetes considered their general practitioner as the health professional most responsible for treating their high blood pressure (88% vs. 92%, $p=0.11$), had at least one visit to a health professional in the previous year (97% vs. 90%, $p<0.0001$), and had their blood pressure measured in the previous year (93% vs. 84%, $p<0.0001$).

Clinical advice for self-management of hypertension

Compared to individuals without diabetes, individuals with diabetes were more likely to report having received clinical advice to control or lose weight if overweight or obese, to engage in physical activity, to limit alcohol consumption if consuming more than recommended, and to make dietary changes, after controlling for gender, age, ethnicity, income, and time since diagnosis (Table 4-2). Individuals with diabetes were not more likely to have received advice on limiting salt intake or reducing smoking.

Engagement in healthy behaviours for blood pressure control

After controlling for gender, age, education, income and time since diagnosis, individuals with diabetes were more likely than those without diabetes to report: limiting alcohol consumption all or most of the time (among those who consumed more alcohol than recommended since diagnosis), measuring their blood pressure at home on a weekly basis, trying to control or lose weight all or most of the time (among those who were overweight or obese), and making changes to their diet all or most of the time. Proportions reporting limiting their salt intake, reducing smoking, or engaging in physical activity did not differ significantly (Table 4-3).

Relationship between receipt of clinical advice and engagement in self-management strategies in individuals with and without diabetes

Average composite health behaviour scores were marginally higher in individuals with diabetes than in those without diabetes (10.4 ± 0.2 vs. 9.6 ± 0.1, p = 0.0002). Individuals who reported receiving more clinical advice for self-management (in terms of number of recommended health behaviours) reported higher levels of engagement in health behaviours for self-management. Specifically, the average healthy behaviour score for an individual who did not receive any advice for health behaviours change was 6.0. This increased, on average, by 1.1 points ($p<0.0001$) for each additional recommendation received after adjustment for potential confounding factors (Table 4-4); the relationship did not differ significantly by presence of diabetes ($p_{interaction} = 0.7$) nor by gender ($p_{interaction} = 0.4$). Highest level of education modified the relationship; in people with high school education or lower, healthy behaviour scores increased by 1.4 points for each additional recommendation received compared to an increase of 1.1 in people with higher levels of education ($p_{interaction} = 0.03$). Time since diagnosis appeared to modify the relationship to a similar extent, but did not reach statistical significance.

Advice on the correct use of a blood pressure monitor was associated with regular home blood pressure monitoring. In individuals without diabetes, those who reported receiving advice on correct use of a blood pressure monitor were 2.6 times (95% CI: 1.7-4.2) more likely to report regular home blood pressure monitoring, after controlling for covariates (data not shown). In the separate stratum of individuals with diabetes, stronger 3.1 fold increase (95% CI: 1.3-7.6) was observed ($p_{interaction}$ = 0.004).

Discussion

Adoption of healthy behaviours is a cornerstone of both hypertension (8, 9) and diabetes management (10). The current study suggests that, among people with hypertension, individuals with coexisting diabetes are slightly more likely to receive advice for healthy behaviours (e.g. exercise, dietary change, and weight control), but as likely to receive advice for dietary salt reduction and smoking cessation. This is consistent with findings from the 1998 *National Health Interview Survey* which, while not considering advice for salt reduction or smoking cessation, showed that people with diabetes were more likely to receive hypertension-specific advice for dietary change (odds ratio 1.9) and exercise (odd ratio 2.0) (11). The relationships observed in the current study were not as strong likely because the odds ratio overestimates the rate ratio when the outcome studied is not rare. People with diabetes were more likely to report making changes to diet, engaging in physical activity, trying to control or lose weight, and regularly monitoring their blood pressure at home, but not limiting their salt intake. Receipt of clinical advice was similarly positively associated with engaging in healthy behaviours in people with and without diabetes (i.e. these groups were equally likely to follow the advice they received). This is in contrast to the 1998 NHIS, which found that people with diabetes were more likely to adhere to advice (11). The current findings do not support our hypothesis that disparities in receipt of clinical advice and adherence to healthy behaviours relate to previously observed disparities in blood pressure control in those with and without diabetes and further study is required to explain observed disparities.

In the current study, people who received advice for multiple behaviours reported higher levels of engagement in lifestyle self-management. The World Health Organization suggests that "moderately intense" primary care interventions, which include targeted information and follow-up, are effective in promoting adoption of healthy behaviours in those at risk for chronic disease (20). In the current survey, the method used to deliver advice was not measured (i.e. what types of information were provided and whether this included follow-up). It is possible that individuals who received more intensive counseling may have been more likely to act on the advice. At the individual level, lifestyle counseling in primary care has been shown to confer small benefits in achieved blood pressure, with 3 of 6 randomized controlled trials showing small (<4 mmHg), significant decreases in blood pressure (21). Small reductions in blood pressure can reduce the burden of cardiovascular diseases at the population level; for example, in persons with and without diabetes small reductions in blood pressure (of -6/-4.6 mmHg and –3.7/–3.3 mmHg, respectively) have been associated with 36% and 11% reductions in total stroke events (22). Furthermore, face-to-face lifestyle counselling is associated with faster achievement of blood pressure control in diabetes; Morrison *et al* showed that counselling rate of one or more per month was resulted in a 3.7 week median time to blood pressure control <130/85 mmHg compared to 5.6 months in those who received counseling less than once per 6 months (23). Individuals who receive advice from health professionals to modify their behaviour may be more confident and motivated to attempt change and sustain changes over time (24, 25).

Although potentially effective, provision of advice for multiple health behaviour change may present a challenge for individual physicians in primary care, as suggested by the current finding that only 45% to 80% of people with hypertension reported ever having received advice for the various behaviours and by like findings in the United States (12, 26). Clinicians may not have sufficient expertise to address the complexities of multiple health behaviour changes (27) nor have sufficient time to do so (28) during brief clinical encounters. Thus, multidisciplinary teams (comprised of physicians, nurses, pharmacists, nutritionists, physical activity specialists, and others) may aid in providing behavioural counseling to patients and have been shown to improve blood pressure control (29-32). Specifically, in a meta-analysis of 27 cluster and randomized control trials of diabetes care with blood pressure as an end-point, Tricco and colleagues showed that changes to team structure (such as multidisciplinary teams, shared cared, or expansion/revision of professional roles) was associated with an average 4.3 mmHg improvement in systolic blood pressure (32). Establishment of multidisciplinary teams in rural populations may present challenges due to limited access and resources (33); potential solutions may include the development of mobile multidisciplinary outreach services, which have been shown to improve blood pressure control in rural populations (34), or telehealth/internet based strategies (35,36).   Because health behaviours are also influenced by the environments in which people live, health professional-led interventions could be further supported by workplace, community, and national initiatives targeting the environmental influences on general health (20, 37).

Some strengths and weaknesses of the current study are noted. This research is strengthened by its use of a large, population-based survey of people diagnosed with hypertension, a survey which provides comprehensive data on factors associated with management of hypertension (14). Furthermore, we produced a novel composite score of clinical advice and of engagement in health behaviours for blood pressure control that could be used in future research. The survey had a good response rate, and participants did not differ from the source population in terms of body weight, physical activity levels, or daily smoking; participants were slightly less likely than the source population to report taking a medication for high blood pressure (83% vs. 89%) (14). The study is limited by the use of cross-sectional data which precluded examination of how behaviours might change over time or how advice may have an impact over time. Furthermore, recall bias may have occurred if people who engage in the recommended behaviours are more likely to remember the advice that they received. Secondly, we could not establish the temporal relationship between advice and behaviour; it is possible that people who engaged in healthy behaviours subsequently initiated conversation with their health care provider about lifestyle change. Canada's Aboriginal on-reserve communities and the three territories were excluded from the sampling frame; as a result, the findings may not generalize to these populations given their higher rates of hypertension and diabetes (38, 39), as well as poorer access to primary care (40). Finally, the use of self-reported data may have led to an overestimate of engagement in behaviours (41) and an underreporting of advice received (42). If individuals who reported receiving advice were more likely to over-report engaging in the behaviour due to social desirability this would have biased the observed associations.

Conclusions

People with hypertension and diabetes were slightly more likely to receive advice from health care professionals on behaviours for hypertension management, with the exception of salt reduction and home blood pressure monitoring, and were as likely as people without diabetes to follow such advice. Health professionals may encourage health behaviour changes in people both with and without diabetes by providing advice and recommendations for these behaviours, with the aim of further improving blood pressure control.

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Table 4-1 Characteristics of Canadian adults age 20 years and older diagnosed with hypertension (n=6135), overall and by diabetes status, 2009 *Survey on Living with Chronic Disease in Canada*.

	Diabetes (n=1170)			No diabetes (N=4965)			χ^2
Characteristics	**N**	**%**	**(95% CI)**	**N**	**%**	**(95% CI)**	**p**
Gender							
Women	554	51.1	(46.0, 56.2)	2702	53.8	(51.9, 55.7)	
Men	616	48.9	(43.8, 54.0)	2263	46.2	(44.3, 48.1)	0.38
Age							
20-39	F	2.3*	(1.0, 3.7)	327	6.7	(5.8, 7.7)	
40-49	72	10.9*	(6.8, 15.0)	427	11.7	(10.0, 13.3)	
50-59	176	25.4	(19.6, 31.2)	821	25.6	(23.3, 27.9)	
60-69	378	31.4	(26.2, 36.7)	1336	25.8	(23.6, 28.0)	
70-79	364	20.7	(17.1, 24.4)	1355	20.0	(18.5, 21.5)	
80+	159	9.2	(7.1, 11.4)	699	10.2	(9.2, 11.2)	0.04
Mean ± standard error		62.9	± 0.6		61.6	± 0.2	0.07
Ethnicity							
White	1056	82.0	(76.7, 87.4)	4613	87.9	(85.5, 90.3)	
Aboriginal off-reserve	51	2.6*	(1.5, 3.7)	123	2.0	(1.5, 2.6)	
Other	58	15.4*	(10.0, 20.8)	203	10.0	(7.7, 12.4)	0.09
Education							
Less than secondary	404	25.6	(21.1, 30.0)	1391	22.5	(20.5, 24.5)	
Secondary school	177	18.0	(12.8, 23.2)	783	17.3	(15.4, 19.2)	
Some post-secondary	77	10.1*	(6.2, 13.9)	281	6.4	(5.2, 7.7)	
Post-secondary graduate	503	45.3	(39.7, 51.0)	2482	53.2	(50.8, 55.5)	0.10
Total household income							
<$15,000	112	9.0*	(5.2, 12.7)	360	5.4	(4.4, 6.4)	
$15,000-$29,999	314	23.4	(18.7, 28.2)	1095	18.6	(16.6, 20.6)	
$30,000-$49,999	262	18.1	(14.6, 21.6)	1087	20.4	(18.5, 22.4)	
$50,000-$79,999	226	24.5	(19.5, 29.6)	1029	23.5	(21.3, 25.7)	
≥ $80,000	156	25.0	(18.7, 31.2)	900	32.1	(29.4, 34.7)	0.04
Marital status							
Married/common-law	661	71.4	(66.9, 75.9)	2866	67.7	(65.4, 70.0)	
Widowed/separated/divorced	399	20.7	(17.3, 24.1)	1625	24.1	(22.1, 26.1)	
Single	110	7.9*	(5.2, 10.6)	467	8.2	(6.8, 9.6)	0.28
Region							
Urban core	609	69.1	(64.8, 73.4)	2644	68.2	(66.2, 70.2)	
Urban fringe	135	6.0	(4.4, 7.5)	604	7.5	(6.5, 8.5)	
Mix of urban/rural	181	9.9	(7.4, 12.5)	844	10.5	(9.3, 11.6)	
Rural	245	15.0	(12.0, 18.0)	873	13.8	(12.4, 15.3)	0.49
Time since diagnosis							
≤2 years	117	10.9	(7.6, 14.2)	776	17.2	(15.2, 19.2)	
3-5 years	200	16.4	(12.5, 20.2)	950	22.0	(19.7, 24.4)	
6-9 years	177	15.9	(11.9, 19.8)	842	18.7	(16.6, 20.8)	
10+ years	640	56.8	(51.0, 62.7)	2257	42.1	(39.8, 44.4)	<0.0001

* Estimate should be interpreted with caution due to high sampling variability (coefficient of variation 16.6% to 33.3%)

F – could not be reported due to high sampling variability (coefficient of variation >33.3%)

Table 4-2 Associations between diabetes status and clinical advice for management of blood pressure, among Canadian adults age 20 years and older with hypertension, 2009 *Survey on Living with Chronic Disease in Canada*

	Diabetes	**No Diabetes**	**Crude**	**Adjusted***
Received advice from a health professional on	**%**	**%**	**PR (95% CI)**	**PR (95% CI)**
Controlling or losing weight	74.9	52.9	1.4 (1.3, 1.5)	1.3 (1.2, 1.4)
Among overweight or obese, n=4214	*81.2*	*65.8*	*1.2 (1.2, 1.3)*	*1.2 (1.1, 1.3)*
Participating in physical activity	78.5	67.9	1.2 (1.1, 1.2)	1.1 (1.0, 1.2)
Limiting alcohol consumption (of those who drank, n=603)	77.6	54.7	1.4 (1.1, 1.8)	1.1 (1.0, 1.2)
Eating certain foods	70.3	61.3	1.2 (1.1, 1.2)	1.1 (1.0, 1.2)
Reducing levels of stress	48.3	44.0	1.1 (1.0, 1.3)	1.1 (1.0, 1.2)
Correct use of home blood pressure monitor	45.8	43.1	1.1 (0.9, 1.2)	1.1 (0.9, 1.3)
Limiting daily salt intake	65.4	63.7	1.0 (0.9, 1.1)	1.0 (0.9, 1.1)
Quitting or cutting down smoking (of those who smoked, n=1484)	80.1	83.3	1.0 (0.9, 1.1)	1.0 (0.9, 1.0)

*adjusted for age group, ethnicity, income, and time since diagnosis based on 5% change in any of the effect estimates, with gender forced into the models

Table 4-3 Crude and adjusted* association between diabetes status and management of blood pressure, among Canadians adults age 20 years and older with hypertension, 2009 *Survey on Living with Chronic Disease in Canada*

Behaviours for blood pressure management	Diabetes %	No Diabetes %	Crude Model PR (95% CI)	Adjusted Model* PR (95% CI)
Limits alcohol consumption all/most of the time (of those who drank, n=603)	69.0	40.4	1.7 (1.3, 2.2)	1.4 (1.1, 1.7)
Measures own blood pressure at home at least weekly	30.2	25.2	1.2 (1.0, 1.5)	1.2 (1.0, 1.5)
Tries to control or lose weight all/most of the time (among those who were overweight or obese, n=4214)	60.2	52.8	1.1 (1.0, 1.3)	1.2 (1.0, 1.3)
Changes to types of food eaten all/most of the time	68.6	59.7	1.2 (1.1, 1.2)	1.1 (1.1, 1.2)
Limits salt consumption all/most of the time	70.2	64.8	1.1(1.0, 1.2)	1.0 (1.0, 1.1)
Quit/reduced smoking all/most of the time (of those who smoked, n=1484)	55.2	58.8	0.9 (0.8, 1.1)	1.0 (0.9, 1.2)
Engages in physical activity all/most of the time	45.6	45.9	1.0 (0.9, 1.1)	1.0 (0.9, 1.2)

*adjusted for education, income, and time since diagnosis based on 5% change in any of the effect estimate, with gender and age group forced into the models

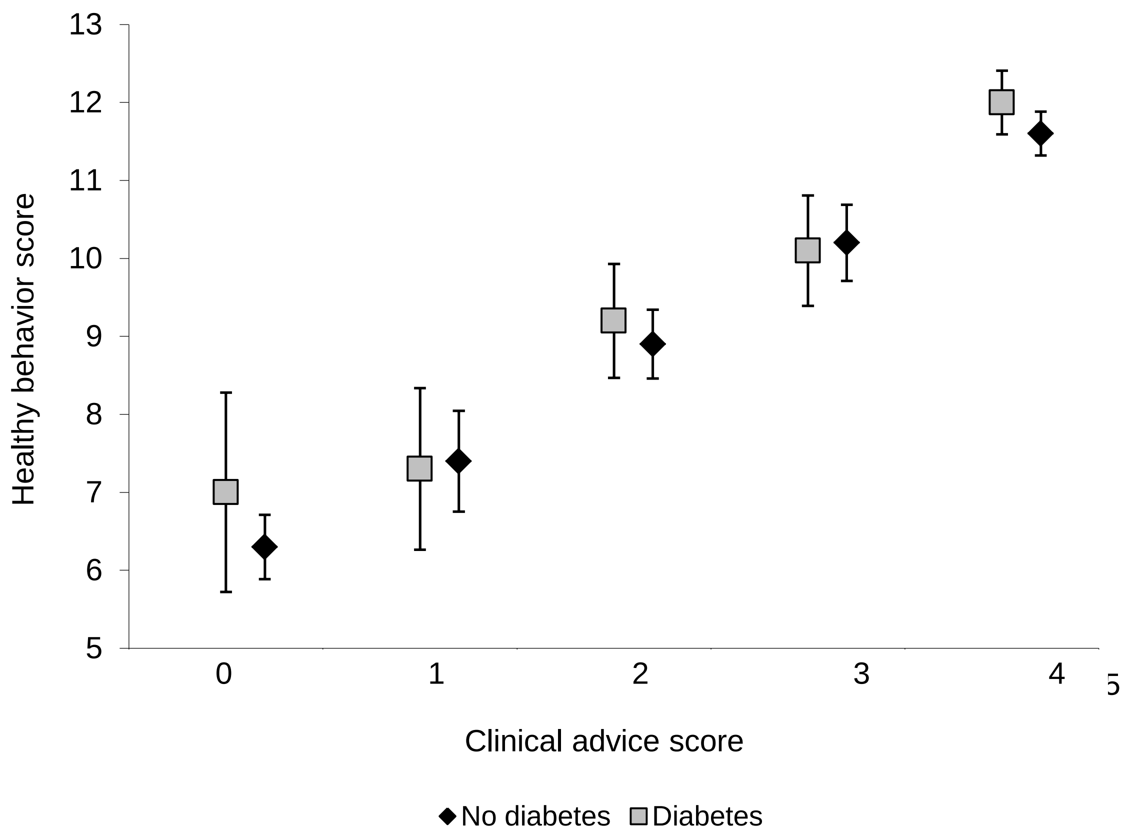

Figure 4-1 Plot of average behaviour score by clinical advice score, stratified by diabetes status, among Canadian adults age 20 years and older with hypertension, 2009 *Survey on Living with Chronic Disease in Canada*

Table 4-4 Linear model for the association between behaviour scores and clinical advice scores, among Canadians adults age 20 years and older with hypertension, 2009 *Survey on Living with Chronic Disease in Canada*

Model	Beta	P value
Intercept	6.0	
Advice score	1.1	< 0.0001
Diabetes	0.5	0.3
Diabetes x Advice Score	- 0.1	0.7
Male	- 0.4	0.3
Male x Advice Score	0.1	0.4
≤ High school education	- 1.1	0.008
≤ High school education x Advice Score	0.3	0.03
Time since diagnosis ≤ 5 years	- 0.6	0.1
Time since diagnosis ≤ 5 years x Advice Score	0.3	0.06
Age (continuous)	0.02	0.001
Ethnicity – Aboriginal off-reserve	0.4	0.3
Ethnicity - Other	0.9	0.07
Total household income <$15,000	- 1.1	0.002
Total household income $15,000 - $29,999	- 0.2	0.4
Total household income $30,000 - $49,999	- 0.5	0.07
Total household income $50,000 - $79,999	- 0.5	0.1
	$R^2 = 0.25$	

Chapter 5

Knowledge of blood pressure targets

in Canadians with hypertension, with and without diabetes

Abstract

Based on a nationally representative cross-sectional sample, we found that 31±2% of Canadian adults with hypertension could recall having ever discussed a blood pressure target with a health professional and could report an appropriate blood pressure target. Among Canadians who recalled discussing a target, individuals with diabetes were less likely to report the recommended target (53% ≤130/80 mmHg) compared to individuals without (69% ≤140/90 mmHg). Canadians with lower education or income were less likely to recall blood pressure targets.

Introduction

Effective communication between health care providers and patients with hypertension may aid in improving patient adherence to therapy and subsequently blood pressure control (1). It has been hypothesized that an important aspect of medical communication is the effective transfer of information, which leads to better informed patients who are more accepting of interventions (1). In their conceptual model of communication phases related to hypertension management, Jolles *et al.* suggest that the information given to patients should be related to current blood pressure levels, targets for blood pressure control, and treatment advice, as these helps form the patient's intention to change behaviour (1). Knowledge of blood pressure targets has been associated with a 3.7 fold greater adherence to antihypertensive medications (2) and individuals not aware of blood pressure targets have been shown to be 60% more likely to have uncontrolled high blood pressure (3).

Recent studies have shown that knowledge of recommended blood pressure targets in the United States is suboptimal, with only 28% and 39% of individuals with hypertension having discussed and knowing the recommended targets for systolic blood pressure and diastolic blood pressure, respectively (4). Furthermore, knowledge of targets among individuals with chronic conditions may also be low; studies of the Veterans Health Administration in the United States have shown that fewer than 50% and 60% of individuals with co-existing coronary artery disease (5) or co-existing diabetes (6), respectively, report appropriate systolic and diastolic blood pressure targets. The extent to which Canadians with hypertension are aware of recommended blood pressure targets is currently unknown, although in a 2003 telephone survey, 32% of Canadians reported that healthy blood pressure was higher than 140/90 mmHg (7). In the current study we describe knowledge of blood pressure targets in Canadian adults with hypertension by diabetes status and sociodemographic characteristics.

Methods

Data from the cross-sectional 2009 *Survey on Living with Chronic Disease in Canada Hypertension Component* were analyzed, a survey of Canadians age 20 years and older who reported having been diagnosed with high blood pressure. Extensive details on the survey are available elsewhere (8). Individuals who refused, did not state an answer, or answered “do not know” to questions about having discussed a blood pressure target with a health professional (n=162) or whether they had diabetes (n=7) were excluded, leaving 5973 respondents available for analysis (representing 4.8 million Canadians with hypertension).

To assess knowledge of blood pressure targets, individuals were asked: "Has a health professional ever discussed a target rate for your blood pressure, that is, the blood pressure level that is best for you?" (Yes vs. no). Individuals who responded "yes" were asked: "What is your target systolic pressure (that is the top or higher number)?" and "What is your target diastolic pressure (that is the bottom or lower number)?" These questions were developed by the Public Health Agency of Canada together with a panel of hypertension researchers (8). Reported blood pressure targets ≤130/80 mmHg and ≤140/90 mmHg were considered in line with Canadian clinical recommendations for people with and without diabetes, respectively (9). For the subpopulation with diabetes, we also considered the general population recommendation (i.e., ≤140/90 mmHg). We described self-reported 1) discussion of a blood pressure target with a health care professional and 2) reporting the recommended target (among those who had discussed a target) by diabetes status, gender and age group, household income, education, ethnicity, and time since hypertension diagnosis.

Data were analyzed using SAS Enterprise Guide version 5 (Cary, NC). Associations were quantified using log-binomial regression to estimate prevalence ratios (PR). Percentages were weighted to reflect the Canadian household population (8). To account for stratification and clustering, 95% confidence intervals (CI) were calculated using bootstrap re-sampling (8).

Results

Approximately half (47%; 95% CI: 45% - 50%) of Canadians diagnosed with hypertension reported ever having discussed a blood pressure target with a health professional. Of these, 66% (95% CI: 62% - 70%) reported a blood pressure target in line with Canadian clinical recommendations. Thus, only 31% (95% CI: 29% - 33%) of Canadians with hypertension (28% and 32% of people with and without diabetes) reported having discussed a blood pressure target and reported a blood pressure target in line with clinical practice guidelines.

Canadians with diabetes were slightly more likely to have discussed a blood pressure target (PR: 1.1; 95% CI: 1.0-1.3), after accounting for age and sex, education, income, ethnicity and time since diagnosis (Table 5-1). However, among Canadians who had discussed a blood pressure target, those with diabetes were less likely to report the recommended target (53% ≤130/80 mmHg) compared to those without diabetes (69% ≤140/90 mmHg), after accounting for covariates (PR: 0.8; 95% CI: 0.7-1.0, p=0.01). People with and without diabetes were equally likely to report the 140/90 mmHg target (66% vs. 69%; PR: 1.0; 95% CI: 0.9-1.1).

Women age 60 years and older were least likely to recall having discussed a blood pressure target compared to other age-gender groups (Table 5-1) but this relationship did not persist after controlling for differences in levels of income and education. In the multivariate analysis, factors negatively associated with having discussed a blood pressure target were lower household income, less than high school education, and white ethnicity. Among individuals who had discussed a blood pressure target, lower levels of education were negatively associated with knowing the recommended targets.

Discussion

These findings suggest that knowledge of recommended blood pressure targets is low in Canada, with less than one third of Canadians with hypertension reporting having discussed a blood pressure target and reporting a blood pressure target in line with clinical practice guidelines. These findings are consistent with those from a survey of 2500 patients of the Kaiser Permanente Medical Care program in the United States, where only 28% and 39% of patients with hypertension had discussed and could report systolic and diastolic pressure targets, respectively (4). It is unclear whether these low rates relate to health care professionals' failure to provide blood pressure target information and/or the often limited ability of patients to retain information from health professionals (10). Provision of verbal messaging together with written or visual information may improve retention (1).

In this study, 53% of people with diabetes reported having discussed a blood pressure target with a health care professional. This finding is similar to findings from the only other study that has examined knowledge of blood pressure targets in this subpopulation (6). In 2003, a survey of the Veterans Health Administration in the United States (n=500, 98% male) showed that 59% of people with diabetes and hypertension reported having a target blood pressure (6). However, knowledge of blood pressure targets was higher in that sample than in our current study. Among American Veterans who had a target, 84% reported systolic <135 mmHg and 94% reported a diastolic target <80 mmHg, respectively (6). In our study, among Canadians who had discussed a target, only 53% reported a target <130/80 mmHg. These differences may reflect the fact that the Veterans Health Administration is an integrated health care system targeting a unique population and our survey targeted a general household population.

In our study, lower socio-economic status was associated with lower likelihood of recalling having discussed blood pressure targets and recalling the recommended targets. Individuals with lower education tend to have more difficulty understanding health information which is compounded by the tendency of health care professionals to give more information to patients with higher levels of education (1). This could potentially be improved by tailoring educational messages to patients' socioeconomic status and educating physicians to improve their communication skills, interventions that have been shown to improve blood pressure in a randomized control trial of low socioeconomic status individuals with uncontrolled hypertension (11).

Conclusion

Less than one in three Canadian adults with hypertension had ever discussed a blood pressure target with a health professional and could report an appropriate blood pressure target, and this was related to diabetes status, education and income levels. Health care professionals may improve retention of blood pressure target information by complementing their verbal discussions with written and visual information, and tailoring messages to meet the needs of patients with lower socioeconomic status (1).

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Table 5-1. Associations between individual characteristics and 1) discussing a blood pressure target and 2) reporting the recommended target*, among those who had discussed one, in Canadians age 20 years and older with hypertension (n=5,920)

	Distribution	Discussed a blood pressure target		Reported recommended target*, among those who had discussed (n=2,654)	
	N	**%**	**Multivariate PR (95% CI)**	**%**	**Multivariate PR (95% CI)**
Diabetes					
No	4835	45.6	Referent	69.1	Referent
Yes	1138	53.3	1.1 (1.0-1.3)	53.4	0.8 (0.7-1.0)
Age and Sex					
Male, 20-59 years	895	51.7	Referent	68.8	Referent
Female, 20-59 years	913	52.0	1.1 (0.9-1.3)	62.6	0.9 (0.8-1.0)
Male, 60+ years	1916	47.0	1.1 (1.0-1.3)	67.1	1.0 (0.9-1.1)
Female, 60+ years	2249	40.6	1.0 (0.9-1.2)	64.4	1.0 (0.9-1.1)
Education					
Post-secondary graduate	2927	52.7	Referent	74.0	Referent
Some post-secondary	347	46.6	0.9 (0.7-1.1)	62.4	0.9 (0.7-1.0)
Secondary school graduate	933	44.3	0.9 (0.8-1.1)	57.3	0.8 (0.7-0.9)
Less than secondary	1731	36.4	0.8 (0.7-0.9)	48.1	0.7 (0.6-0.9)
Total household income					
≥ $80,000	1043	57.8	Referent	72.5	Referent
$50,000-$79,999	1224	48.6	0.8 (0.7-0.9)	68.9	1.0 (0.9-1.1)
$30,000 - $49,999	1318	46.2	0.8 (0.7-0.9)	63.5	0.9 (0.8-1.0)
$15,000 - $29,999	1353	39.4	0.7 (0.6-0.9)	53.8	0.9 (0.7-1.0)
<$15,000	461	35.4	0.7 (0.5-0.9)	68.5	1.0 (0.8-1.2)
Ethnicity					
White	5519	45.6	Referent	66.8	Referent
Aboriginal off-reserve	169	56.9	1.3 (1.0-1.6)	62.8	0.9 (0.7-1.2)
Other	255	57.0	1.3 (1.1-1.5)	60.1	1.0 (0.8-1.2)
Time since diagnosis					
Less than 2 years	881	53.0	Referent	59.0	Referent
3-5 years	1119	47.6	0.9 (0.7-1.1)	74.2	1.2 (1.0-1.5)
6-9 years	992	46.6	0.9 (0.8-1.1)	71.9	1.2 (1.1-1.4)
≥10 years	2826	46.1	0.9 (0.8-1.0)	63.1	1.1 (1.0-1.3)

*≤130/80 mmHg for individuals with diabetes and ≤140/90 mmHg for individuals without diabetes

Chapter 6

Validity of self-reported blood pressure control in people with hypertension attending a primary care centre

Abstract

Objectives: To estimate the validity of self-reported blood pressure control and medication use in people with hypertension, with and without diabetes.

Methods: In a sample of 161 patients with hypertension in a family health team in Ontario, we applied questions from the *2009 Survey on Living with Chronic Disease in Canada Hypertension Component* and compared responses against objectively measured and chart-abstracted clinical indicators. Objective blood pressure control was defined as <130/80 mmHg and <140/90 mmHg for individuals with and without diabetes.

Results: Self-reported blood pressure control showed reasonable sensitivity in people with and without diabetes (83% ± 11% and 78% ± 10%) but low specificity (30% ±19% and 58% ± 21%, respectively.) In the subgroup with diabetes, specificity improved to 88% ± 11% when blood pressure control was defined based on a 140/90 mmHg target. Self-reported and chart-abstracted numbers of prescribed antihypertensive medications showed fair agreement (kappa=0.7); 9% and 14% of patients overestimated and underestimated the number of prescribed medications, respectively.

Conclusion: While most individuals with controlled hypertension reported having controlled blood pressure, a large proportion of individuals with uncontrolled hypertension also reported that their blood pressure was controlled. This level of misclassification suggests that in a family

medicine clinic population and in health survey contexts, a self-reported measure of blood pressure control may not be useful for assessing hypertension control.

Introduction

Surveillance and monitoring of blood pressure and hypertension are critical factors in the effort to prevent and control hypertension (1). Population-based surveys that employ objective blood pressure measurements, such as the *National Health and Nutrition Examination Survey* in the United States and the *Canadian Health Measures Survey*, provide a much needed picture of high blood pressure prevalence, awareness, treatment, and control (2-4). In some settings, such as telephone surveys, objective blood pressure measurements are not feasible and inclusion of self-reported measures of blood pressure control have been used as an alternative to objective measures (5), as such reports could theoretically allow risk factors for and outcomes of uncontrolled high blood pressure to be examined.

For example, in 2009, the Canadian federal government fielded the national telephone-administered *Survey on Living with Chronic Disease in Canada* to assess the knowledge, attitudes and behaviours of Canadians with hypertension (5). Among the many items measured as part of the telephone interview (6), participants were asked whether their blood pressure was generally well-controlled, borderline, high, or low, as well as the number of medications taken for high blood pressure, and the timing of their most recent clinic blood pressure assessment. It remains unclear, however, whether these measures can be used to accurately assess blood pressure control, medication use, and recent blood pressure assessments.

To date, no study has considered the accuracy of a simple self-reported interview question to assess blood pressure control in patients with hypertension. While a number of studies have compared self-recorded home blood pressure readings against those recorded objectively by a home blood pressure monitor (7-9) or against those measured in a clinic (10), the results do not foster a better understanding of the extent to which individuals with hypertension can accurately report their general level of blood pressure control in an interview setting. Thus, the primary objective of the current study was to estimate the validity of self-reported blood pressure control, as assessed in the national survey protocol (6), in people with hypertension with and without diabetes (since clinically recommended blood pressure targets differ between these groups in some countries such as Canada i.e., <130/80 mmHg vs. <140/90 (11, 12).) As a secondary objective, we sought to validate items describing self-reported timing of most recent blood pressure assessment by a health professional and self-reported numbers of antihypertensive medications, as these reflect important indicators of clinical management (1, 13). Validation of these measures may support or discourage their inclusion in future self-reported surveys conducted at national and other levels.

Methods

Source of study population: Participants were recruited from the patient roster of the Queen's Family Health Team, an interdisciplinary primary care practice of family physicians, nurse practitioners, and other health professionals, serving approximately 14,000 residents of Kingston, Ontario, Canada and its surrounding areas. The study protocol was approved by the Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics board (Appendix

C.) All of the family physicians who practice in this setting (n=20) consented to have their patients eligible for selection into the study.

Inclusion criteria: Participants were eligible if they were aged 20 years or older, were not currently pregnant, and presented in the electronic medical record with an ICD-9 diagnostic code for hypertension (401, 402, 403, 404, 405) on November 15th, 2011 (n=1319) or May 9th, 2012 (n=945, which excluded individuals selected as part of the November sample); 99% of patients had a diagnosis of essential hypertension (ICD-9 401). Patients were randomly selected from the electronic medical record in strata defined by diabetes status, sex, and age (<65 vs. ≥65 years) in order to try to ensure an equal split of people with and without diabetes and to reflect the age-sex distribution of Canadians with hypertension (sampling fractions shown in Appendix D.) Each patient's eligibility was reviewed by their family physician; patients were ineligible for the study if their physician deemed them unable to provide informed consent or unable to attend the clinic. Numbers of eligible, selected, excluded and participating patients are summarized in Figure 6-1.

Recruitment: Seven hundred and fifty-two eligible participants (n=375 November sample and n=378 May sample) were sent letters and an information sheet signed by their family physician inviting them to participate. Individuals who did not initially respond were sent reminder postcards (14). In wave one (November 2011 to April 2012), 68 individuals agreed to participate. In wave two (May to September 2012), 93 individuals agreed to participate. The sample size was calculated to provide estimates of sensitivity and positive predictive values that would fall within 10% of the true value 95% of the time, with emphasis on precision of these estimates rather than representativeness of the sample. Since individuals with diabetes were oversampled and older men were more likely to participate, estimates were weighted to reflect the distribution of Canadians with diagnosed hypertension from the 2009 *Survey on Living with Chronic Diseases in Canada* based on diabetes status, gender, and age (<65 vs. ≥65) in an effort to improve representativeness.

Clinic procedure: All participants received an information sheet and consent form to read, discuss and sign (Appendix G). A 5 minute in-person structured interview was conducted, using a short version (21 questions - Appendix H) of Statistics Canada's 2009 *Survey on Living with Chronic Disease in Canada* hypertension questionnaire (available at www.statcan.gc.ca) (15). Following the interview, blood pressure was assessed using a BpTRU™ BP-200 device (BpTRU Medical Devices Ltd., Coquitlam, British Columbia). An appropriately sized cuff was chosen based on measured upper arm circumference: small adult (18-26 cm), regular adult (26-34 cm), large adult (32-43 cm) and extra-large adult (41-52 cm). The cuff was fastened around the participant's arm, with the centre of the bladder over the brachial artery and lower margin of the cuff 2-3 cm above the antecubital fossa (elbow crease). Participants were seated, with both feet on the floor, and with back and arm supported so that the elbow crease rested and the cuff was positioned in line with the heart with the palm of the hand facing down. Respondents were left alone and asked to sit quietly, relax and refrain from moving or talking for a five minute rest period. After the rest period, the interviewer re-entered the room to start the BPTru, remained in the room for the first measurement to ensure proper functioning, and left the room for the remaining five measurements. Average systolic blood pressure and diastolic blood pressure were calculated automatically based on the last five of six measurements.

Chart review: After the interview and blood pressure assessment, the electronic medical records were reviewed by the interviewer using an abstraction form (Appendix I), and then reviewed a second time to ensure completeness and confirm the accuracy of data abstraction. The "measurements", "prescriptions" and "disease registry" modules of the Open Source Clinical Application Resource (OSCAR, McMaster University, Hamilton, Ontario) electronic chart interface were reviewed for information on up to 8 systolic and diastolic blood pressure measurements within one year preceding the interview (typically measured using BPTru), antihypertensive medications (Appendix J) prescribed at the time of interview, diabetes status, and diagnosis of comorbidities for which certain antihypertensive medications are often prescribed (i.e. chronic kidney disease, edema, migraine, heart failure, arrhythmia, myocardial infarction, and angina).

Key measures and definitions: Blood pressure control*:* Individuals were asked: "In general, do you consider your blood pressure to be: *1) Well-controlled (normal, fine, ok); 2) Borderline; 3) High; 4) Low*". Individuals were classified as controlled if they reported "well-controlled" or "low" blood pressure and uncontrolled if they reported "borderline" or "high" blood pressure. Controlled blood pressure (well-controlled or low) was compared against BPTru blood pressures measured on the interview day. In order to account for daily variation in blood pressure, self-reported blood pressure control was also compared against 1) the most recently recorded systolic and diastolic blood pressure in the electronic medical record and 2) the average of up to 8 blood pressure readings recorded in the electronic medical record in the previous year.

Both objectively-measured and chart-abstracted blood pressure control were defined according to a <140/90 mmHg threshold for the subgroup without diabetes and according to a <130/80 mmHg threshold for the subgroup with diabetes (10, 70). In sensitivity analyses, we explored the effects of defining blood pressure control 1) using a 140/90 mmHg threshold for all participants, including those with diabetes 2) using a 135/85 mmHg threshold (71) and 3) using BpTRU measurements adjusted to reflect sphygmomanometer readings, according to the validated equations: adjusted systolic blood pressure = 11.4 + (0.93 x BpTRU systolic blood pressure) and adjusted diastolic blood pressure = 15.6 + (0.83 x BpTRU diastolic blood pressure) (72).

Number of antihypertensive medications: As part of the interview, respondents were asked how many medications they were currently taking for high blood pressure. Self-reported number (0, 1, 2, 3, 4+) was compared against active prescriptions at the time of interview, as recorded in the prescriptions module of the electronic medical record.

Timing of most recent blood pressure assessment: Participants were asked: "When was the last time you had your blood pressure measured by a health professional? Was it: *1) Less than 1 month ago?; 2)1 month to less than 3 months ago?; 3) 3 months to less than 6 months ago?; 4) 6 months to less than 1 year ago?; 5) 1 year to less than 2 years ago?; 6) or 2 or more years ago?"*

Self-reported responses were compared against the timing of the most recently measured blood pressure recorded in the electronic medical record.

Analysis: Sensitivity and specificity were calculated as measures of validity for self-reported blood pressure control, and positive and negative predictive values were calculated in order to determine the expected yield in a survey setting, overall and stratified according to diabetes status, gender, and age (<65 vs. ≥ 65 year). As previously stated, estimates were weighted to reflect the age-sex distribution and the prevalence of diagnosed diabetes in Canadians with diagnosed hypertension from the 2009 *Survey on Living with Chronic Diseases in Canada.* Agreement between self-reported and chart-abstracted number of antihypertensive medications and timing of most recent blood pressure assessment were estimated via the kappa statistic.

Results

Characteristics of the study population are shown in Table 6-1. Individuals with diabetes ranged in age from 46 to 88 years, with an average age of 69 ± 10 years; 51% were women. Individuals without diabetes ranged in age from 36 years to 94 years, with an average age of 68 ± 13 years; 54% were women. The majority in both groups (93% and 87%) were taking antihypertensive medication. Resistant hypertension, defined as uncontrolled high blood pressure despite concurrent use of 3 or more antihypertensive medications (17), affected 3% of the study population (4% and 3% of those with and without diabetes). In people with diabetes, prevalence of blood pressure control based on self-report was 79% compared to 67% based on measured blood pressure (defined as blood pressure <130/80 mmHg). In people without diabetes, prevalence of blood pressure control based on self-reports was 70% compared to 77% based on measured blood pressure.

Validity of self-reported blood pressure control in people with and without diabetes:

In people with diabetes, sensitivity and specificity of self-reported blood pressure control were 83% (95% CI: 72% to 94%) and 30% (95% CI: 11% to 49%), respectively, when compared to BPTru™ blood pressures <130/80 mmHg (Table 6-2). When blood pressure control was defined based on a 140/90 mmHg threshold, sensitivity and specificity improved to 87% (95% CI: 78% to 98%) and 88% (95% CI: 52% to 99%).

In people without diabetes, sensitivity and specificity of self-reported blood pressure control were 78% (95% CI: 68% to 88%) and 58% (95% CI: 37% to 79%), respectively, meaning that, of people with blood pressure controlled <140/90 mmHg on the day of interview, approximately four in five reported having well-controlled or low blood pressure (controlled) and, of people who had uncontrolled blood pressure (≥140/90 mmHg) on the day of interview, nearly three in five reported that it was borderline or high (uncontrolled).

Results were generally unchanged in sensitivity analyses that used a 5 mmHg lower threshold for defining blood pressure control (Appendix K) or BPTru measurements adjusted to reflect sphygmomanometry (Appendix L). When self-reported blood pressure control was compared to blood pressure the last time it was measured in the clinic (obtained through chart-abstraction), sensitivity estimates remained unchanged (83% and 82% for people with and without diabetes), while specificity decreased to 24% and 50% for those with and without diabetes. Similar findings were observed when self-reports were compared to the average of up to 8 blood pressure measurements taken over the previous year (Appendix M).

Validity of self-reported number of antihypertensive medications:

Self-reported and chart-abstracted number of antihypertensive medications showed fair agreement (kappa=0.6; 95% CI: 0.5-0.7) and this did not differ by diabetes status (Table 6-3.) Seventy-seven percent of people accurately reported the number of antihypertensive medications prescribed, 14% underestimated the number of prescriptions (13% by 1 medication and 1% by 2+ medications), and 9% overestimated the number of prescriptions (7% by 1 medication and 2% by 2+ medications). In participants with a chronic condition for which antihypertensive medications can be prescribed (i.e. chronic kidney disease, edema, migraine, heart failure, arrhythmia, myocardial infarction, or angina), agreement decreased (kappa=0.4).

Validity of self-reported timing of most recent clinic blood pressure assessment:

Self-reported timing of most recent blood pressure assessment showed fair agreement (kappa=0.5; 95% CI: 0.4-0.6) with chart-abstracted timing. Sixty-five percent of participants accurately reported the time since last blood pressure measurement, with 27% reporting that it had occurred more recently than it had, and 8% reporting that it had occurred longer ago than it had. Ninety-eight percent of individuals reported having a clinic blood pressure assessment in the previous year, with 95% agreement (data not shown).

Discussion

We showed, in a sample of people with hypertension from a family medicine clinic, that self-reported blood pressure control had reasonable sensitivity but low specificity. This means that in a survey setting, while four in five individuals with controlled blood pressure will report that it is controlled, a large proportion of individuals with uncontrolled high blood pressure will also report that it is controlled (40%-70%). The amount of misclassification introduced by this self-reported measure of blood pressure control suggests that it may not be useful for assessing prevalence of hypertension control or determining associations in survey settings. Self-reported number of prescribed medications showed fair agreement with chart-abstracted information. Self-reported receipt of a clinic blood pressure assessment in the previous year was accurate for 95% of participants.

In our clinic-based sample of patient volunteers, a large proportion (40-70%) of individuals with objectively measured uncontrolled high blood pressure incorrectly reported that their blood pressure was controlled. We expect that this self-reported measure of blood pressure control would perform worse when administered by telephone to general household sample, since our low response rate likely resulted in a volunteer sample with greater awareness of their level of blood pressure control than the general Canadian population. Compared to the general population with diagnosed hypertension, our volunteer sample (that was weighted in order to improve representativeness) had greater knowledge of the recommended blood pressure targets and had been diagnosed for a longer period of time. Furthermore, since BPTru™ is used regularly in the clinic from which the patient sample was drawn, the study patients may have had a greater opportunity to see their own results. From this, it may be reasonable to infer that accuracy of self-reported blood pressure control would be lower when administered in other settings. If required, this could be confirmed at the population-level by including the questions on a national physical measures survey. In our own setting in Canada, this might involve inclusion of the questions on a future cycle of the *Canadian Health Measures Survey*. In the meantime, the results of the current study suggest that the self-reported measure of blood pressure control has insufficient validity to be employed in large population-based surveys and other settings.

A strength of the study was that comparisons were made with blood pressures on the day of the interview as well as those previously measured in the clinic, in order to account for daily variability in blood pressure. Furthermore, we used an automated blood pressure monitor to assess blood pressure control; the main advantage of this method is that blood pressure measurements are taken in an automated fashion in the absence of an observer, thereby eliminating observer errors, digit preference, and reducing white-coat hypertension (18). Inter-rater variability was avoided since a single interviewer administered all interviews and blood pressure assessments.

A limitation of the study was that, while providing a reasonable amount of precision around estimates of sensitivity, the small sample size did not provide the same level of precision for specificity given the high prevalence of blood pressure control. A second limitation was that we did not compare self-reported number of antihypertensive medications against number of medications measured by recording drug identification numbers directly from medication pill bottles (19). Instead, self-reports were compared against chart-abstracted numbers of antihypertensive medications, which could have included discontinued medications. Furthermore, timing of most recent blood pressure assessment was compared against timing in the medical record, which would not have included assessments made outside of the clinic, such as those made during hospital visits, cardiac rehabilitation sessions, or in other clinical settings. Furthermore, since the population studied was socio-demographically homogeneous, we could not explore the effect of factors such as ethnicity and language on validity (1). Finally, it is unclear on what information patients based their self-reported blood pressure assessments, considering that accuracy was not improved when self-reported blood pressure control was compared to chart-abstracted blood pressure values and that only 17% of the sample reported regularly monitoring their blood pressure at home.

We validated an existing self-reported measure of blood pressure control from the *2009 Survey on Living with Chronic Disease in Canada* and found that the majority of individuals with uncontrolled high blood pressure incorrectly reported that their blood pressure is controlled. This level of misclassification suggests that a self-reported measure of blood pressure control may not be sufficiently valid (sensitive and specific) in order to be useful for assessing hypertension control in health surveys administered in clinical settings or large population health surveys administered by telephone.

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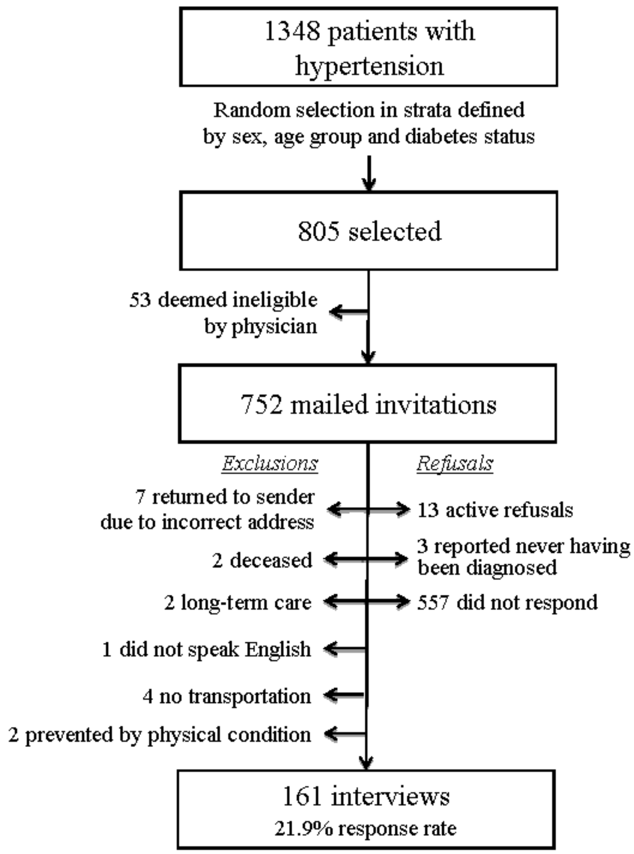

Figure 6-1. Inclusion and exclusion flowchart of participants with hypertension attending the Queen's Family Health Team, Kingston, Ontario, Canada, 2012

Table 6-1 Characteristics of the participants with hypertension attending the Queen's Family Health Team, Kingston, Ontario, Canada, 2012

	No Diabetes (n=96)			Diabetes (n=65)		
	N	**%**	**Weighted %**	**N**	**%**	**Weighted %**
Female	52	**54**	**54**	20	**31**	**51**
Age ≥65 years	56	**62**	**42**	45	**69**	**46**
Blood pressure controlled						
Self-reported (*missing=3)*	69	**73**	**70**	54	**84**	**79**
BPTruTM	72	**75**	**77**	42	**65**	**67**
Last clinic measurement	56	**58**	**62**	26	**40**	**42**
Clinic measurements over previous year	61	**64**	**69**	22	**34**	**40**
Measures blood pressure at home at least weekly	17	**18**	**15**	11	**17**	**11**
Reported recommended blood pressure target	53	**56**	**58**	32	**52**	**52**
Number of self-reported antihypertensive medications						
0	9	**10**	**12**	5	**8**	**7**
1	44	**47**	**47**	25	**39**	**38**
2	28	**30**	**27**	22	**34**	**38**
3+	13	**14**	**13**	12	**19**	**16**
Missing=3						

Table 6-2 Comparison between self-reported blood pressure control and blood pressure control on the day of interview (BPTru) in participants with hypertension attending the Queen's Family Health Team, Kingston, Ontario, Canada, 2012, overall, and by diabetes status, gender and age.

	TP	FP	TN	FN	Se (95% CI)	Sp (95% CI)	PPV(95% CI)	NPV(95 % CI)
Overall*	93	30	17	18	79 (72-87)	51 (35-67)	82 (75-90)	46 (31-60)
By Diabetes status** (using a <130/80 mmHg threshold for people with diabetes and a <140/90 mmHg threshold for people without diabetes)								
No	57	12	12	13	78 (68-88)	58 (37-79)	86 (77-94)	45 (27-64)
Yes	36	18	5	5	83 (72-94)	30 (11-49)	71 (58-83)	47 (21-74)
By Diabetes status (using <140/90 mmHg threshold)								
No	57	12	12	13	78 (68-88)	58 (37-79)	86 (77-94)	45 (27-64)
Yes	52	2	4	6	87 (78-96)	88 (52-99)	98 (90-99)	44 (18-71)
By Gender								
Men	48	24	8	7	83 (73-93)	37 (18-56)	75 (64-85)	49 (27-72)
Women	45	6	9	11	75 (64-87)	63 (45-92)	90 (81-99)	44 (23-64)
By Age (years)								
<65	28	8	8	10	71 (57-85)	65 (40-90)	86 (74-98)	56 (22-65)
≥65	63	21	8	7	89 (82-96)	33 (14-51)	65 (70-88)	48 (28-76)

TP – true positives; FP – false positives; TN – true negatives; FN – false negatives; Se – sensitivity; Sp – specificity; PPV – positive predictive value; NPV – negative predictive value

*Proportions were weighted to reflect the sex, age (<65 vs ≥ 65 years) and diabetes status distribution of the Canadian population diagnosed with hypertension from 2009 *Survey on Living with Chronic Diseases in Canada*

Table 6-3 Agreement between self-reported and chart-abstracted number of antihypertensive medications in participants with hypertension attending the Queen's Family Health Team, Kingston, Ontario, Canada, 2012.

	Overall			No Diabetes (n=94)			Diabetes (n=64)			Without a condition for which antihypertensive medication may be prescribed* (n=117)			With a condition for which antihypertensive medication may be prescribed* (n=41)		
	N	%†	(95% CI)	N	%†	(95% CI)	N	%†	(95% CI)	N	%†	(95% CI)	N	%†	(95% CI)
Accurately reported	112	77	(70-84)	72	80	(72-89)	40	65	(53-76)	90	83	(76-89)	22	58	(40-75)
Underestimated by 1 medication	26	13	(8-18)	12	10	(4-16)	14	24	(14-34)	14	9	(4-15)	12	26	(11-42)
Underestimated by 2+ medications	4	1	(0-3)	0	0		4	5	(0-11)	1	0	(0-0)	3	4	(0-12)
Overestimated by 1 medication	14	7	(3-11)	8	7	(2-12)	6	6	(0-12)	11	6	(2-11)	3	9	(0-19)
Overestimated by 2+ medications	2	2	(0-4)	2	2	(0-5)	0	0		1	2	(0-4)	1	3	(0-9)
Missing=3	$\kappa^{\dagger}$ = 0.7 (95% CI:0.6-0.8)			$\kappa^{\dagger}$ = 0.7 (95% CI:0.6-0.8)			$\kappa^{\dagger}$ = 0.5 (95% CI:0.3-0.6)			$\kappa^{\dagger}$ = 0.7 (95% CI:0.6-0.8)			$\kappa^{\dagger}$ = 0.4 (95% CI:0.2-0.6)		

* chronic kidney disease, edema, migraine, heart failure, arrhythmia, myocardial infarction, or angina

†Proportions and kappa were weighted to reflect the sex, age (<65 vs ≥ 65 years) and diabetes status distribution of the Canadian population diagnosed with hypertension from 2009 *Survey on Living with Chronic Diseases in Canada*

Chapter 7

Adjustment for binary exposure misclassification in logistic regression using probabilistic sensitivity analyses: an example

Preamble. The original intent within the thesis had been to use the probabilistic sensitivity analysis method to quantify the amount of bias and uncertainty introduced by self-reported blood pressure control in association with receipt of advice and having a blood pressure target. However, when applied, the estimates of sensitivity and specificity for self-reported blood pressure control from the validation study (Chapter 3) resulted in negative cell counts and simulation intervals that ranged from 0 to 300, making them non-interpretable. This issue is further discussed in the General Discussion (Chapter 8 section 8.5)

In order to meet the planned methodological objective of the thesis, established at the proposal stage, I instead tested the probabilistic sensitivity analysis method in the context of associations between self-reported overweight/obesity and self-reported physical inactivity with hypertension and uncontrolled high blood pressure.

Abstract

Objective: To 1) determine whether a published probabilistic sensitivity analysis method accurately assesses the amount of bias and uncertainty introduced to odds ratios by misclassification; and 2) to demonstrate the impact of assuming non-differential misclassification in bias analysis when differential misclassification exists, within the context of a study of cardiovascular health.

Methods: We compared self-reported overweight/obesity and physical inactivity, from two combined cycles of the *Canadian Health Measures Survey* (2007-2009 and 2009-11; n=5,649), with objective measures to estimate sensitivity and specificity and used these data to test the quantitative assessment of bias in relationships with hypertension and treated but uncontrolled high blood pressure using a published probabilistic sensitivity analysis method. Odds ratios from probabilistic sensitivity analyses were compared to the results from conventional logistic regression that modeled the effects of objectively-measured overweight/obesity and physical inactivity.

Results: The probabilistic sensitivity analysis did not perform as consistently for multivariate associations as it did for the bivariate associations. For example, in multivariate analysis, the odds ratio for the association between self-reported overweight/obesity and hypertension was slightly biased away from the null compared to objectively-measured overweight/obesity (OR: 2.47 vs. 2.41). In multivariate probabilistic sensitivity analysis, the OR was further biased away from the null (OR: 2.67). Ignoring observed minor differential misclassification inflated the ORs estimated from probabilistic sensitivity analysis in certain contexts.

Conclusion: Until misclassification errors are well understood for comparison groups and covariates under investigation in any given study, bias analyses may not adequately safeguard against the biasing effects of misclassification.

Introduction

Understanding associations between risk factors and disease hinges on correct interpretation of accurate and precise effect estimates (1). Obtaining accurate and precise effect estimates depends, in part, on the validity of the measurement technique employed. Often times, in order to gain a larger or more representative sample, to work within a given budget, and/or to minimize participant burden and risks, an optimal measurement technique is sacrificed for a less accurate measure, in which case misclassification will bias the results. Despite its known potential for introducing bias (2-5), misclassification is often discounted as a major threat to the validity of epidemiologic research findings (6).

When acknowledged as a limitation, it is often assumed that misclassification errors are exactly non-differential and independent (1, 7). Based on this assumption, investigators and readers may erroneously conclude that the true association is stronger than that observed (1). Bias aside, misclassification also affects the precision of effect estimates. Conventionally, uncertainty around an estimate is described using a 95% confidence interval (CI) that considers only random error. However, the amount of uncertainty around an estimate also depends on systematic errors, such as the amount of misclassification (8). As such, investigators may fail to recognize that a confidence interval represents the minimum amount of uncertainty around an estimate and, as a result, run the risk of drawing conclusions with overconfidence (1).

To help researchers better address bias and uncertainty introduced by misclassification, bias analysis methods have been developed (9-12). Fox and colleagues developed a probabilistic sensitivity analysis method that quantifies the amount of bias and uncertainty introduced to odds ratios by a misclassified binary exposure or outcome variable (12). Using this method, ranges of sensitivity and specificity are used to recreate probable datasets that could have been observed had the individuals been classified correctly. From each reconstructed dataset, an odds ratio is estimated to create a distribution of corrected odds ratios; the mean and the 2.5^{th} and 97.5^{th} percentiles represent the odds ratio and 95% simulation interval, which is comparable to a 95% confidence interval except that is also accounts for the systematic error introduced by misclassification. The two main advantages of this method, as compared to formulae for back-calculating two-by-two tables (4), are that it quantifies the amount of uncertainty introduced by misclassification and it allows for estimation in the context of a multivariate analysis.

Although researchers have been called on to quantify the magnitude and direction of misclassification errors prior to presenting research findings (1, 4, 13-15), few studies have applied probabilistic methods to real-world data in order to do so (8, 16, 17). Bodnar *et al*. investigated the impact of misclassification in categorical self-reported pre-pregnancy body mass index on associations with adverse pregnancy outcomes, showing that non-differential misclassification likely biased odds ratios away from the null (16). In that study, the authors used external validation results to inform the probabilistic sensitivity analysis (16). In another illustration of the probabilistic method, Jurek *et al.* reanalyzed data from a case-control study of self-reported first degree relatives' breast cancer history and breast cancer risk (18). Various scenarios for differential misclassification were tested, with estimates of sensitivity and specificity for self-reported family breast cancer history informed by 5 external validation studies. Corrected odds ratio were stronger (ranging from 1.89 to 2.46) than the odds ratio estimated from the original data (OR: 1.63). Finally, only one known study has used internal validation data to inform probabilistic sensitivity analyses. Lash *et al.* considered the effects of imperfect reliability (abstractor agreement), determined in a subsample of cohort participants, on hazard of breast cancer recurrence (17). In that study, the hazard ratios for 25 risk factors were generally unchanged when imperfect, albeit very good, reliability was factored in, but uncertainty around the estimates increased (17).

While the above studies have demonstrated application of the probabilistic sensitivity analysis method, to our knowledge no study has shown that the method can accurately estimate the odds ratio based on 'gold-standard' exposure (thereby quantifying bias accurately) nor demonstrated the implications of improperly specifying misclassification parameters (such as assuming non-differential misclassification when differential misclassification exists) using real data. In this study, we have used cardiovascular risk factor data from an existing population-based national study of Canadians. We compared self-reported body mass index and physical activity with objective measures to estimate sensitivity and specificity and used these data to demonstrate the quantitative assessment of bias in relationships with hypertension and treated but uncontrolled high blood pressure using a published probabilistic sensitivity analysis method (12). We compare the results of this method to the associations observed using objectively measured BMI and physical inactivity to 1) determine whether the method accurately accounts for misclassification in various scenarios and 2) to demonstrate the potential consequence of assuming non-differential misclassification when differential misclassification exists.

Methods

Data Source and Study Population

Data from two cycles of the *Canadian Health Measures Survey* (2007-2009 and 2009-11) were combined in this analysis. The CHMS is a household population survey for Canada. The CHMS sampled respondents using a multistage cluster design, details of which are described in detail elsewhere (19-21). The combined cycle data are weighted to account for non-response and to ensure that the sample assumes the demographic distribution of the 2006 Census population (19). Exclusions at the design stage were individuals living on First Nations reserves, Crown lands, in institutions and in certain remote regions, and full-time members of the regular Canadian Forces (19).

We further restricted the analysis to the 5,697 adults age 20 to 79 years of age with complete activity monitor (accelerometry) data. Individuals who did not have their blood pressure measured (n=2), pregnant women (n=38), individuals with missing hypertension medication (n=4) and diabetes status information (n=4) were excluded, leaving 5,649 individuals for analyses.

Blood Pressure Outcomes

During the household interview, individuals were asked “In the past month, have you taken medicine for high blood pressure?” On an appointed date after the interview, systolic and diastolic blood pressures were each measured at a mobile examination clinic using the BpTRU™ BP-300 device (BpTRU Medical Devices Ltd., Coquitlam, British Columbia). Respondents were left alone and asked to sit quietly, relax and refrain from moving or talking for a five minute rest period. After the rest period, the health measures specialist re-entered the room to start the BPTru, remained in the room for the first measurement to ensure proper functioning, and left the room for the remaining five measurements (22). Average systolic and diastolic blood pressures were calculated from the last 5 of 6 blood pressure measurements, taken one minute apart (22).

<u>Hypertension</u> was defined either as a measured mean systolic blood pressure of 140 mmHg or higher, a measured mean diastolic blood pressure of 90 mmHg or higher, or the respondent’s report of blood pressure medication use in the past month. For individuals with diabetes,

hypertension was defined based on a 130/80 mmHg cut-point, as per the current Canadian hypertension recommendations (23).

Treated but uncontrolled blood pressure: Among individuals who reported taking medication for high blood pressure in the previous month, individuals were considered as having uncontrolled high blood pressure if they had either a systolic blood pressure ≥ 140 mmHg or a diastolic blood pressure ≥ 90 mmHg (or ≥ 130/90 mmHg for individuals with self-reported diabetes.)

Exposures

Self-reported overweight/obesity: During the household interview, respondents were asked "How tall are you without shoes on?" and "How much do you weigh?" Body mass index was calculated as weight in kilograms divided by height in metres squared (kg/m^2). Individuals with a self-reported BMI ≥25 kg/m^2 were considered overweight or obese (24).

Objectively measured overweight/obesity: During the mobile clinic examination scheduled after the household interview, a specialist measured standing height and weight, using a ProScale M150 digital stadiometer (Accurate Technology Inc., Fletcher, USA) and a Mettler Toledo VLC with Panther Plus terminal scale (Mettler Toledo Canada, Mississauga, Canada) (20,25).

Self-reported physical inactivity: During the household interview, participants were read a list of 20 common moderate and vigorous intensity activities and for each were asked to indicate the number of times they performed the activity over the previous 3 months and the average duration on each occasion (22). Average minutes of weekly leisure-time moderate-to-vigorous physical activity were calculated from the activities lasting on average >15 minutes, using the following equation: Minutes/week = Σ (N_i x D_i/13), where N_i is the number of occasions of activity *i* during the 3 months prior to collection and D_i is the average duration, in minutes, of activity *i* on each occasion (26). Duration was recorded in categories (1-15 minutes, 16-30 minutes, 31-60 minutes, 60+ minutes); these categories were recoded as 0 (to exclude short bouts), 23.5 min, 45.5 min, and 60 min, respectively (26). Respondents were considered physically inactive if they accumulated less than 150 minutes of moderate-to-vigorous physical activity per week on average (24) in bouts of 15 minutes or more.

Objectively-measured physical inactivity: Following the mobile clinic examination, which was scheduled after the household interview, respondents were asked to wear an Actical accelerometer (Phillips – Respironics, Oregon, USA) over their right hip during their waking hours for 7 days (27). The accelerometer measures intensity of physical activity in intervals of 1 minute. As per existing precedents, respondents with 4 or more valid days of wear time were retained for analyses; a valid day was defined as 10 or more hours of wear time determined by subtracting non-wear time (i.e., 60 consecutive minutes of zero counts with allowance for 1 to 2 minutes of counts between 0 and 100) from 24 hours (27).

The current Canadian guidelines for the prevention and treatment of cardiovascular disease recommend that adults accumulate at least 150 min of moderate-to-vigorous intensity aerobic physical activity per week, in bouts of 10 min or more (24). Average daily time spent in bouts of moderate-to-vigorous physical activity was derived by summing time spent in bouts of such activities on all valid days, and dividing by the number of valid days (20). To count as a bout, at least 8 out of 10 consecutive minutes of accelerometer observations had to exceed the moderate intensity cut-point (i.e. ≥ 1535 counts/minute) (27). The average daily volume of moderate-to-vigorous physical activity was multiplied by 7 to obtain a weekly total, and the 150 minutes/week cut-point was used to define active vs inactive.

Analysis

Conventional analysis: Associations between exposures (self-reported and objectively measured overweight/obesity and physical inactivity) and outcomes (hypertension (yes/no) and treated but uncontrolled blood pressure (yes/no)) were quantified using bivariate and multivariate weighted logistic regression. Variables considered as potential confounders in multivariate analyses were: age-gender group (male 20-59, female 20-59, male 60-79, and female 60-79 years); diabetes status (yes/no); white race (yes/no); education (post-secondary graduate, some post-secondary education, high school graduate, < high school); total household income (≥ $80,000; $50,000-$79,999; $30,000-$49,999; $0 - $29,999); marital status (married/common-law vs single/divorced/separated/widowed); smoking status (never, former, occasional, daily); high alcohol consumption (yes/no; defined as ≥ 2 drinks/day or ≥ 14 drinks/week for men or ≥ 9 drinks/week for women(24)), and salt always added to food at the table or during cooking (yes/no) (28, 29). Other more comprehensive measures of salt consumption (e.g., from 24-hour food records or urine collection) were not obtained in the CHMS. Covariates were retained if their exclusion caused a ≥5% change in the odds ratio from the fully adjusted models (5). Point estimates and odds ratios were weighted to reflect non-response and the demographic distribution of the 2006 Canadian Census population (19), with 95% confidence intervals estimated using bootstrap resampling methods (20).

Probabilistic sensitivity analysis: In order to quantify the amount of bias and uncertainty introduced by the self-reported (misclassified) exposures, we used a modified SAS macro developed by Fox *et al* (12) (available at: https://sites.google.com/site/biasanalysis/sensmac) to apply record-level corrections for misclassification (i.e. sensitivity and specificity estimates) in Monte Carlo simulations. We modified the macro to use the survey weights in weighted logistic regression.

Sensitivity and specificity were calculated from the CHMS data and stratified by hypertension status and treated but uncontrolled blood pressure status, in order to investigate the potential for differential misclassification. Estimates of sensitivity, specificity, and the positive and negative predictive values were weighted (19), with 95% confidence intervals estimated using bootstrap resampling methods (20). We applied both the overall and stratified estimates of sensitivity and specificity in probabilistic sensitivity analysis to demonstrate the impact of ignoring small departures from non-differentiality.

The probabilistic sensitivity analysis simulated the data that would have been observed had the individuals been classified correctly. Although sensitivity and specificity were known with certainty in the current study (since both objective and self-reported information were available for all subjects), in most situations accuracy is not known with certainty and estimates are drawn from external validation studies. To illustrate the effects of this uncertainty, the range of probable sensitivity and specificity parameters (i.e., the 95% confidence intervals) were input with a triangular distribution. From these distributions, values of sensitivity and specificity were randomly selected and then the observed data were used to calculate the positive and negative predictive values (the probabilities of being correctly classified). These probabilities were applied to the individual records in a Bernoulli trial. Relationships between exposures and outcomes were quantified using weighted logistic regression on the reconstructed dataset. This process gives only one potential reconstructed data set and one summary odds ratio (OR). The process was then repeated 50,000 times, based on existing precedent (18), to create a distribution of corrected ORs. This process yielded a frequency distribution of odds ratios; the 2.5th and 97.5th percentiles of the back-calculated point estimate distribution is the 95% simulation interval (SI) that accounts for both the systematic and random error.

Results

Characteristics of the study population are in Table 1. Overall, 21% of the study population had hypertension, and of those treated for hypertension, 1 in 4 had uncontrolled high blood pressure. Three in 5 participants (61%) were overweight/obese based on measured height and weight, which was similar to the proportion based on self-reported height and weight (56%). Eighty-five percent of study participants were classified as physically inactive based on accelerometry, compared to 48% based on self-reported leisure-time physical activities.

Accuracy of self-reported overweight/obesity and physical inactivity are in Table 2. Sensitivity and specificity were high for self-reported overweight/obesity and were approximately non-differential. Self-reported physical inactivity had low sensitivity; of people who were physically inactive based on accelerometry, only 1 in 2 were classified as inactive based on self-report. For physical inactivity, misclassification was differential: specificity differed among people with and without hypertension (90% vs 75%) and sensitivity differed among people with and without treated but uncontrolled high blood pressure (64% vs 51%).

Table 3 presents the associations of objectively-measured and self-reported (ie., misclassified) overweight/obesity and physical inactivity exposures with hypertension and treated but uncontrolled high blood pressure based on conventional logistic regression, which are compared to the results from probabilistic sensitivity analyses using differential and non-differential estimates of sensitivity and specificity.

Objective 1: Determine whether the probabilistic sensitivity analysis method accurately accounts for misclassification

When differential sensitivity and specificity estimates were used, the bivariate odds ratios from probabilistic sensitivity analysis were consistent with the odds ratios estimated based on objectively-measured exposures (Table 3). For example, people who were inactive based on accelerometry had 2.28 times the odds of having hypertension compared to people who were active. This relationship was biased towards the null (OR=1.12) when self-reported inactivity was used in the conventional logistic regression. When differential sensitivity and specificity estimates were used in probabilistic sensitivity analysis, the odds ratio for the self-reported physical activity assessment was corrected to 2.26 while widening the margin of error around the estimate. The same successful correction was also observed for the associations of overweight/obesity with hypertension and physical inactivity with treated but uncontrolled high blood pressure. For the relationship between overweight/obesity and treated but uncontrolled high blood pressure, the method did not adjust the association, but all estimates were close to 1.0 with wide margins of error.

The probabilistic sensitivity analysis did not perform as consistently for multivariate associations as it did for the bivariate associations. For example, people who were overweight/obese based on measured height and weight had 2.41 times the odds of hypertension, after controlling for physical activity, age, gender, diabetes, ethnicity, income and smoking. This relationship was slightly biased away from the null when the self-reported overweight/obesity variable was used (OR: 2.47), and further biased away from the null in probabilistic sensitivity analysis (OR: 2.67). On the other hand, for the relationship between self-reported overweight/obesity and treated but uncontrolled high blood pressure the method appeared to work reasonably well. The varying performance of the probabilistic sensitivity analysis in multivariate contexts may depend on differences in the confounding effects of the covariates; associations between the covariates and the exposures are shown in Appendix O.

Objective 2: Demonstrate the potential consequence of assuming non-differential misclassification when differential misclassification exists

Ignoring small differences in sensitivity and specificity between comparison groups had varying effects on the results. For example, accuracy of self-reported overweight/obesity was high and was approximately non-differential between people 1) with and without hypertension and 2) with and without uncontrolled high blood pressure among those treated (Table 2). Among the former, ignoring a 4% difference in sensitivity and a 2% difference in specificity inflated the OR by

133% but, among the latter, ignoring similar differences had a negligible effect on the OR (Table 3). In the case of physical inactivity and hypertension, ignoring a 14% absolute difference in specificity inflated the OR by 123%. For the relationship between physical inactivity and treated but uncontrolled high blood pressure, ignoring a 13% absolute difference in sensitivity resulted in negative cell counts for the simulation models in probabilistic sensitivity analysis and, as a result, the odds ratio could not be estimated.

Discussion

We used data from a national study of Canadians with both objectively measured and self-reported body mass index and physical inactivity information to demonstrate quantification of the amount of bias and uncertainty introduced by misclassification within the context of cardiovascular risk factors and hypertension. This study has two important new findings: 1) probabilistic sensitivity methods do not perform as predictably in multivariate situations; 2) ignoring small departures from non-differentiality or using inaccurate estimates of sensitivity and specificity can bias the results of probabilistic methods.

In this study, probabilistic sensitivity analyses did not perform as accurately for multivariate logistic regression as it did for bivariate logistic regression. When the differential estimates of sensitivity and specificity were used, the correction for misclassification was nearly perfect for the bivariate OR but had unpredictable results in the multivariate scenarios. One of the main purported advantages of record-level corrections is that they allow covariates to be considered in the analysis, but it is unclear whether this advantage holds true in real-world contexts. We hypothesize that differences between the probabilistic sensitivity analysis OR and the OR estimated from conventional logistic regression using the objective exposures is due to the way that covariates associate with the self-reported vs objective exposures (as shown in Appendix O) or the way that misclassification errors relate to covariates, problems that may also explain why negative cell counts were produced in some multivariate contexts.

We also show that probabilistic sensitivity analyses require careful selection of sensitivity and specificity in order to correctly estimate bias and uncertainty due to misclassification (8). In the current study, we were fortunate to make use of internal validation data to inform the probabilistic sensitivity analysis and could compare our results to those obtained using the 'gold standard' exposure. We showed that ignoring small departures from non-differentiality could bias the results of probabilistic sensitivity analyses. In many study contexts, epidemiologists would likely rely on external validation data, which may not estimate sensitivity and specificity for the comparison groups of interest. It may then become easy to revert to assuming that misclassification is non-differential, an assumption that can bias the probabilistic sensitivity analysis. Furthermore, results from external validation studies may not apply to a population under investigation and their use could result in misleading adjustments. So, although epidemiologists and others have been increasingly called upon to quantify the magnitude and direction of systematic errors (4,13,14), for which probabilistic methods are a useful tool, this is difficult to accomplish without high quality validation studies that examine the potential for differential misclassification and that are generalizable.

A strength of the current study is that we used population-based data and (rarely available) internal validation data to compare the results from probabilistic sensitivity analyses to the relationship observed using the objective exposure measures. A limitation was that we did not account for the complex multistage cluster sampling design of the CHMS survey in the probabilistic sensitivity analysis, and as a result the simulation intervals are likely too narrow (since random error was underestimated). We converted categorical self-reported physical activity into a continuous measure to match the physical activity guidelines; this involved truncating the highest category (60+ minutes) which would negatively skew the distribution. However this is a typical derivation done by Statistics Canada in estimating physical activity levels in Canada (26) and would have had the effect of improving estimates of accuracy, since physical activity estimates based on accelerometry are much lower. We used objectively-measured overweight/obesity and physical activity based on accelerometry to estimate the validity of self-reported measures. While these may not be perfect "gold standard" measures to calculate sensitivity and specificity, they were sufficient to illustrate the effects of misclassification on associations and correction for these effects. Furthermore, to simplify the illustration, we forced a dichotomy on overweight/obesity and physical inactivity and did not apply previously published methods for accounting for misclassification in a polytomous exposure (16).

It has been argued that the use of probabilistic bias analyses may have the potential to safeguard against the tendency of researchers to assume non-differential misclassification and bias towards the null (1,13). In this study we found that, although probabilistic sensitivity analysis is a tool that can be used to quantify this bias and uncertainty, it performs inconsistently in multivariate logistic regression and requires careful selection of validity estimates. We conclude that, until misclassification errors are well understood for the comparison groups and covariates under investigation in any given study, bias analyses may not adequately safeguard against the biasing effects of misclassification.

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Table 7-1 Characteristics of the study population, Canadians aged 20-79 years, 2007-2011.

	Distribution	
	N	**%†**
Outcomes		
Hypertension	1348	20.8
Uncontrolled high blood pressure (among those treated for hypertension)	231	24.8
Exposures		
Overweight/obese – objectively measured	3557	61.2
Overweight/obese – self-reported	3234	56.0
Physically inactive – objectively measured	4842	85.2
Physically inactive – self-reported	2622	48.2
Covariates		
Age and sex		
Male, 20-59 years	1766	39.5
Female, 20-59 years	2142	39.0
Male, 60-79 years	842	10.3
Female, 60-79years	899	11.2
Has diabetes	326	5.3
White race	4739	80.8
Highest level of education		
Postsecondary graduate	3630	63.0
Some postsecondary education	393	8.7
High school graduate	877	16.4
Less than high school	702	11.8
Total household income		
≥ $80,000	2126	41.9
$50,000-$79,999	1412	24.9
$30,000-$49,999	1093	18.5
$0 - $29,999	880	14.6
Married/common-law	3807	67.1

High alcohol consumption	775	14.2
Self-reported smoking		
Never smoker	2813	50.7
Former smoker	1831	29.9
Occasional smoker	181	3.7
Daily smoker	812	15.8
Salt always added to food	1780	33.3

† weighted proportion

Table 7-2. Accuracy of self-reported overweight/obesity and physical inactivity compared to objective measures in Canadian adults age 20-79 years, overall and by hypertension status and blood pressure control status

	(N)	TP	FP	TN	FN	Se (95% CI)	Sp (95% CI)	PPV (95%CI)	NPV (95% CI)
Self-reported overweight/obesity compared to measured overweight/obesity									
Overall	(5564)	3123	108	1955	378	89 (86 - 91)	95 (94-97)	97 (96-98)	84 (81-88)
No hypertension	(4232)	2161	83	1705	283	88 (85 - 91)	96 (94-97)	96 (95-97)	86 (82-90)
Hypertension	(1332)	962	25	250	95	92 (90 - 95)	93 (89-98)	98 (97-99)	76 (69-82)
Among those treated for htn	(1031)	767	17	172	75	92 (89-95)	93 (89-98)	98 (97-99)	72 (65-80)
Treated and controlled	(804)	593	13	139	59	92 (86-95)	93 (86-99)	98 (97-100)	72 (65-80)
Treated but uncontrolled	(227)	174	F	33	16	92 (86-97)	96 (87-100)	99 (98-100)	72 (49-96)
Self-reported physical inactivity compared to measured physical inactivity									
Overall	(5649)	2459	163	648	2379	53 (49-56)	77 (71-83)	93 (91-95)	22 (19-25)
No hypertension	(4301)	1827	143	523	1808	52 (48-56)	75 (69-82)	91 (89-94)	24 (20-28)
Hypertension	(1348)	632	20	125	571	54 (50-58)	90 (85-94)	98 (97-99)	14 (12-17)
Among those treated for htn	(1045)	483	14	96	452	55 (50-59)	92 (86-97)	99 (98-100)	15 (11-18)
Treated and controlled	(814)	377	F	74	354	51 (45-57)	92 (85-99)	99 (97-100)	14 (9-19)
Treated but uncontrolled	(231)	106	F	22	98	64 (54-75)	90 (81-99)	99 (97-100)	18 (10-25)

TP – true positives; FP – false positives; TN – true negatives; FN – false negatives; Se – sensitivity; Sp – specificity; PPV – positive predictive value; NPV – negative predictive value

Table 7-3. Association of objectively-measured and self-reported overweight/obesity and physical inactivity with 1) hypertension and 2) uncontrolled high blood pressure among Canadians adults age 20-79 years, Canadian Health Measures Survey

	Conventional logistic regression		Probabilistic sensitivity analysis	
	Objectively measured exposure OR (95% CI)	Self-reported exposure OR (95% CI)	Self-reported exposure, correction for differential misclassification OR (95% SI)	Self-reported exposure, correction for nondifferential misclassification OR (95% SI)
Overweight/obesity				
Association with hypertension				
Bivariate	2.97 (2.15-4.09)	2.84 (2.15-3.76)	3.02 (2.35-3.91)	4.11 (3.18-5.46)
Multivariate*	2.41 (1.65-3.51)	2.47 (1.79-3.41)	2.67 (2.00-3.60)	3.67 (2.72-5.11)
Association with treated but uncontrolled high blood pressure				
Bivariate	1.01 (0.42-2.41)	0.94 (0.47-1.86)	0.92 (0.49-2.04)	0.90 (0.52-1.82)
Multivariate*	0.91 (0.40-2.04)	0.85 (0.42-1.69)	0.88 (0.43-2.11)	0.86 (0.45-1.86)
Physical inactivity				
Association with hypertension				
Bivariate	2.28 (1.70-3.06)	1.12 (0.92-1.36)	2.26 (0.89-8.80)	2.79 (1.56-26.0)
Multivariate**	1.69 (1.29-2.21)	1.10 (0.89-1.36)	2.26 (0.86-9.01)	2.83 (1.49-25.66)
Association with treated but uncontrolled high blood pressure				
Bivariate	1.00 (0.50-2.03)	1.62 (0.95-2.75)	0.92 (0.12-10.74)	Nondifferential sensitivity and specificity resulted in negative cell counts in simulation models
Multivariate**	0.90 (0.46-1.78)	1.55 (0.86-2.77)	0.92 (0.12-10.74)	

*adjusted for moderate-to-vigorous physical activity (minutes/week –continuous), age-gender group, diabetes status, non-white ethnicity, total household income, and smoking, based on a 5% change in any of the effect estimates. Education, marital status, alcohol, and 'salt always added to food' were not retained.

**adjusted for measured body mass index (continuous), age-gender group, diabetes status, non-white ethnicity, education, smoking, alcohol, and 'salt always added to food', based on a 5% change in any of the effect estimates. Marital status and total household income were not retained

Chapter 8

General discussion

8.1 Overview

The overall purpose of this thesis was to better understand the distribution and determinants or factors potentially influencing blood pressure control in Canadians with hypertension, with and without diabetes. The thesis attempted to answer four questions:

1. Are Canadians with both hypertension and diabetes more likely to have uncontrolled high blood pressure compared to Canadians with hypertension alone?
2. Are Canadians with diabetes less likely to receive and follow advice for health behaviours currently recommended for the treatment of hypertension? Are they less likely to be aware of the recommended blood pressure targets?
3. Is self-reported blood pressure control a valid way of measuring blood pressure control in a clinic-based survey setting?
4. Does a published sensitivity analysis method accurately account for the bias introduced to associations by misclassified variables? What are the consequences of improperly specifying misclassification parameters in these sensitivity analyses?

8.2 Summary of key findings

Key findings of this thesis are as follows:

Are Canadians with both hypertension and diabetes more likely to have uncontrolled high blood pressure compared to Canadians with hypertension alone?

The findings from my analysis of the *Canadian Health Measures Survey* suggest that, in 2007 to 2009, fewer Canadians with diabetes were treated to their recommended treatment target. Among people with hypertension, 56% and 64% of people with and without diabetes had controlled high blood pressure. Among those treated with antihypertensive medications, Canadians with diabetes were significantly less likely to be treated to their recommended target (63% <130/80 mmHg) compared to individuals without diabetes (83% <140/90 mmHg; $OR_{adjusted}$: 0.3; 95% CI: 0.2-0.6). A disparity in control was not observed between individuals with and without diabetes at the 140/90 mmHg threshold, in contrast to previous findings (1, 2). Individuals with diabetes were taking more antihypertensive medications on average but were less likely to be physically active and have a healthy body weight (based on body mass index and waist circumference.) The rate of hypertension control in Canadians with diabetes is almost two-fold higher than control rates reported in the United Kingdom (3) and the United States (4), and is much higher than that observed in Canada in 1986-1992 (5).

Are Canadians with diabetes less likely to receive and follow advice for health behaviours currently recommended for the treatment of hypertension? Are they less likely to be aware of the recommended blood pressure targets?

The second study in my thesis showed that, among people with hypertension, individuals with coexisting diabetes were slightly more likely to report receiving advice for healthy behaviours (e.g. exercise, dietary change, and weight control), but as likely to report receiving advice for dietary salt reduction and smoking cessation. People with and without diabetes were equally likely to follow the advice that they received. These findings do not support my hypothesis that disparities in receipt of clinical advice and adherence to healthy behaviours relate to previously observed disparities in blood pressure control in those with and without diabetes. With respect to knowledge of blood pressure targets, Canadians with diabetes and hypertension were less likely to report the recommended target (53% ≤130/80 mmHg) compared to Canadians with hypertension alone (69% ≤140/90 mmHg), but were equally likely to report the ≤140/90 mmHg target. Knowledge of recommended blood pressure targets was low in Canada, with less than one in three Canadians with hypertension reporting having discussed a blood pressure target <u>and</u> reporting a blood pressure target in line with clinical practice guidelines (6).

Is self-reported blood pressure control a valid way of measuring blood pressure control in a clinic-based survey setting?

In my fourth study, I tested the validity of the self-reported measure of blood pressure control included in the *2009 Survey on Living with Chronic Diseases in Canada* and found that the question may not be sufficiently valid to be useful for assessing hypertension control in health surveys administered in clinical settings or large population health surveys administered by telephone. Self-reported blood pressure control had reasonable sensitivity but low specificity (i.e., sensitivities of 83% and 78%; specificities of 30% and 58% for people with and without diabetes, respectively.) This suggests that in a survey setting, four in five individuals with controlled blood pressure will report that their blood pressure is controlled and a large proportion of individuals with uncontrolled high blood pressure will also report that their blood pressure is controlled. This misclassification will have the effect of biasing prevalence estimates and measures of association.

Does a published sensitivity analysis method accurately account for the bias introduced to associations by misclassified variables? What is the consequence of improperly specifying misclassification parameters in these sensitivity analyses?

Misclassification in variables, such as self-reported blood pressure control and/or related health behaviours, can result in misleading estimates of association. I evaluated a published probabilistic sensitivity analysis method designed to account for such bias (7) by comparing associations between obesity, physical activity and blood pressure control based on objectively-measured exposures, self-reported exposures, and self-reported exposures corrected for misclassification. I found that the probabilistic sensitivity analysis method did not perform as accurately for multivariate logistic regression as it did for bivariate logistic regression. Furthermore, probabilistic sensitivity analyses require careful selection of sensitivity and specificity parameters in order to correctly estimate bias and uncertainty due to misclassification. I found that by ignoring small departures from non-differentiality, bias could be introduced to the results of probabilistic sensitivity analyses.

8.3 Strengths

The thesis was strengthened by its use of large surveys that were designed to be nationally representative, which improves power as well as the generalizability of the studies' findings. As such, the findings provide results for the Canadian context that can be used to inform future hypertension surveys and evidence-based efforts to prevent and control hypertension (8). Throughout the thesis (in Chapters 3, 6, and 7), the use of an automated blood pressure monitor had the advantage of eliminating observer errors, digit preference, and reducing white-coat hypertension (9), which improves the precision and accuracy of estimates of blood pressure control. However, in both the *Canadian Health Measures Survey* and the validation study a one-time blood pressure measurement was used as a proxy for usual blood pressure control and as a result some misclassification may have occurred. In the case of the validation study, I also estimated the sensitivity and specificity of self-reported blood pressure control compared to blood pressures recorded over the previous year in the clinic and findings were generally unchanged. I also confirmed many of the findings in the thesis by performing sensitivity analyses that adjusted blood pressure to reflect sphygmomanometry, which allowed greater comparability with national surveys from other countries that relied on sphygmomanometry. The methodological paper that evaluated the probabilistic sensitivity analysis was strengthened through its use of rarely available internal validation data to compare the results from probabilistic sensitivity analyses to the relationships observed using the objective exposure measures.

8.4 Limitations of the thesis

There are a number of limitations that may affect the internal and external validity of the studies' findings. These include 1) the cross-sectional nature of the surveys; 2) the use of self-reported measures of engagement in healthy behaviours and covariates; 3) the small sample sizes; and 4) low response rates in the *Canadian Health Measures Survey* and the validation study. As discussed below, these factors limited my ability to address temporality, increased the opportunity for bias, resulted in low study power in some cases, and may have affected generalizability.

8.4.1 Temporality

The cross-sectional nature the surveys limited my ability to determine temporality (i.e., whether the exposure precedes and, as a result, is more likely to be a cause of the outcome). In the case of the first manuscript that described blood pressure control in people with diabetes, this represents a minor limitation since the primary intention was to determine whether people with diabetes are more likely to *have* uncontrolled high blood pressure. From these analyses we cannot infer that having diabetes *causes* uncontrolled high blood pressure because temporality cannot be established; there is some evidence that incidence of diabetes is higher in individuals with uncontrolled high blood pressure compared to people with controlled blood pressure (10, 11).

The objective of the second manuscript was to determine whether receipt of advice *influences* engagement in health behaviours for blood pressure control, and in this case the inability to establish temporality is also a limitation. It is possible that engagement in behaviours influences receipt of advice, if for example, people who engaged in healthy behaviours subsequently initiated conversation with their health care provider about the lifestyle changes they had made, which they then recall as advice received. Furthermore, because these data were cross-sectional, we do not know to what extent physical activity or adiposity changed over time in response to a diagnosis of hypertension.

8.4.2 Bias

8.4.2.1 Survival bias

The finding that people with diabetes *have* more uncontrolled high blood pressure could represent an even higher risk of *not achieving* blood pressure control in this group, since the cross-sectional association may be subject to survival bias that arises when duration of a health state (such as uncontrolled high blood pressure) is different between comparison groups (i.e. people with and without diabetes). Although much of the risk of cardiovascular disease in diabetes results from hypertension, diabetes remains a risk factor for cardiovascular disease mortality independent of hypertension (12) ; thus, people with diabetes and uncontrolled blood pressure may be more likely to die prior to their counterparts without diabetes or their diabetic counterparts with controlled blood pressure. This in essence reduces the likelihood of people with both diabetes and uncontrolled high blood pressure being selected into the *Canadian Health Measures Survey* sample and can bias the association when measured cross-sectionally. The question of whether people with diabetes are less likely to *achieve* blood pressure control requires a prospective cohort study comparing time-to-blood pressure control following diagnosis.

8.4.2.2 Reporting biases

In general, the use of self-reported measures of receipt of advice and adherence to lifestyle management strategies was a major limitation of Manuscript 2. In particular, *social desirability bias* and *recall bias* may have affected the associations. In the *Survey on Living with Chronic Disease* protocol respondents were asked about advice that they received for health behaviours before questions about engagement; it is possible that individuals who reported receiving advice from their health professional may have over-reported their engagement in these behaviours due to a greater perceived social desirability (i.e., their doctor told them to do it so they feel they should say they are doing it). Along the same lines, recall bias may have occurred if people who engage in the recommended behaviours were more likely to remember the advice that they received. Likewise, it is unclear whether people with diabetes may be more likely to over-report receipt of advice and engagement. As I demonstrated in Manuscript 5 (Chapter 7), misclassification can have unpredictable effects on study results. Thus, it is crucial for future surveys of this nature to include well-validated self-reported measures so that the effects of misclassification can be properly evaluated.

8.4.3 Statistical Power

The analyses of the *Canadian Health Measures Survey* and the validation study also suffered from small sample sizes. In the case of the former, the analysis was underpowered to detect differences according to demographic characteristics in the subsample with diabetes and thus I could not identify correlates in this subpopulation with certainty. Furthermore, I could not consider ethnic or vulnerable populations, as this would involve analysis of smaller sub-samples that would provide unstable estimates. In the case of the validation study, the small sample size resulted in wide margins of error around estimates of sensitivity and specificity.

8.4.4 Generalizability

Both the *Canadian Health Measures Survey* and the validation study had low response rates, which could compromise the external validity of the study findings if people who participated in these studies were systematically different from people who did not. The likelihood of such bias is difficult to determine, since little information is available for people who declined to participate. In the case of the *Canadian Health Measures Survey*, which had a similar response rate to other national surveys such as the *National Health and Nutrition Examination Survey* (13), participants were first invited to participate by telephone, then interviewed in person, and then asked to attend a mobile clinic for a physical measures examination. It is unclear whether people who agreed to participate differed from those who declined when first contacted by telephone. It does not appear that presentation to the clinic imposed a further selection pressure; individuals who did and did not attend the clinic were similar in terms of self-reported body mass index, health utility index scores, access to a regular medical doctor, and use of medications (14).

In the validation study that I conducted, I found that, compared to the general population with diagnosed hypertension, the volunteer sample had greater knowledge of the recommended blood pressure targets and had been diagnosed for a longer period of time. It is unclear whether these differences arose due to selection or are true differences between the Queen's Family Health Team source population and the general Canadian population. In either case, I would expect that the self-reported measure of blood pressure control would perform worse when administered by telephone to a general household sample, since the volunteer sample likely had greater general knowledge of hypertension.

8.5 Changes from the original thesis proposal

The original intent of the thesis had been to determine whether diabetes-related disparities in blood pressure control were associated with differences in knowledge of blood pressure targets, receipt of advice, and engagement in healthy behaviours. I had intended to correct for imperfect accuracy in self-reported blood pressure control (as determined in Manuscript 4 - Chapter 6) using a probabilistic sensitivity analysis method (which I evaluated in Manuscript 5 - Chapter 7). However, when I attempted to use the probabilistic sensitivity analysis method to account for the imperfect accuracy of self-reported blood pressure control, the results were not informative for the following reasons. First, many of the iterations resulted in negative cell counts. Take for example the weighted two-by-two table for self-reported blood pressure control by diabetes status based on the 2009 *Survey of Living with Chronic Disease* dataset (Table 8-1). If we consider the estimates of sensitivity and specificity of self-reported blood pressure control observed for people with and without diabetes in Manuscript 4 (sensitivities= 0.83 and 0.78; specificities= 0.30 and 0.53) and apply them using equation 8.1 (below) for back-calculating cell frequencies (15) , we obtain the cell frequencies in Table 8-2, which are impossible.

[Equation 8.1]

A= (A*-FpN)/ (Se+Sp-1)

Where

A = True number with outcome

A* = Measured number with outcome

Fp = False-positive probability = 1-Sp

N = Total sample size

Se = Sensitivity

Sp = Specificity

Furthermore, when I used the wide margins of error around sensitivity and specificity to inform the probabilistic sensitivity analysis, the resulting odds ratios had extremely wide simulation intervals (ranging from 0 to 300), making the results uninformative. Because I could not confidently rely on such results, I chose not to relate knowledge of blood pressure targets, receipt of advice, and engagement in healthy behaviours to diabetes-related disparities in blood pressure control based on self-report. Instead, I demonstrated my knowledge of and ability to apply the probabilistic sensitivity analysis in the context of commonly self-reported health behaviours and their relationship to blood pressure control.

8.6 Public health and clinical contributions

The findings from this study can still inform the planning and evaluation of Canadian efforts to prevent and control hypertension. In 2007, the Canadian Hypertension Education Program and the Canadian Diabetes Association called on health care professionals to redouble their efforts in helping patients with diabetes achieve appropriate blood pressure targets (16), based on previous findings from the *Ontario Blood Pressure Study,* which showed that people with diabetes were less likely to have their blood pressure controlled below 140/90 mmHg (1). It was unclear whether this finding was specific to Ontario or also represented a disparity in Canada as a whole. I found that, at the national level, nearly half of all Canadians with diabetes are above the hypertension treatment target. This finding was identified as one of the major Canadian hypertension "care gaps" in 2011 (8).

The study of receipt of advice and engagement in healthy behaviours, while perhaps less robust, still has some important messages. Although I showed that receipt of advice from health professionals may influence patients' intentions to engage in these behaviours, I also showed that

20% to 55% of Canadians with hypertension did not recall ever receiving advice for the various clinically-recommended health behaviour changes. In addition, the majority of Canadians with hypertension reported either having never discussed a blood pressure target or could not recall the recommended target. Furthermore, although many people with hypertension reported trying to change their behaviours, analysis of the *Canadian Health Measures Survey* suggests that many people with hypertension continue to have lifestyles that put them at higher risk for adverse outcomes. These analyses may suggest the need to further support health professionals in their health behaviour counseling efforts. Because the environments in which people live also influence the engagement in healthy behaviours, health professional-led interventions could be further supported by workplace, community, and national initiatives that make healthier choices the easy ones (17) .

8.7 Methodological contributions

The thesis also makes a contribution to the measurement of hypertension control. Manuscript 4 (Chapter 6) is the first study to determine whether respondents can accurately report their level of blood pressure control on a questionnaire. This measure has been included on two cycles of the *Survey on Living with Chronic Disease in Canada* and the findings of this study suggest that this question should not be included on another cycle. Manuscript 5 (Chapter 7) is the first study to my knowledge that has assessed whether a published method for accounting for misclassification can accurately estimate true associations, or demonstrated the implications of improperly specifying misclassification parameters. Based on the findings of this study, I would suggest that researchers not employ such sensitivity analyses until they are demonstrated to work in multivariate contexts and until misclassification errors are well understood for the comparison groups under investigation.

8.8 Directions for future research

In my opinion, there remains a need to understand why people with diabetes are less likely to have their blood pressure controlled to target compared to people without diabetes, while acknowledging that this disparity relates to the lower treatment target for people with diabetes. Understanding reasons for lack of control in diabetes likely requires a large prospective cohort study of people with and without diabetes, that includes robust measures of adherence to health behaviours and medication, and that follows individuals from first diagnosis. While conducting this thesis research, I separately found that older women were less likely to have their blood pressure controlled compared to older men (findings that are not presented as part of this thesis (18,19)); this disparity did not appear to be due to differences in health behaviours or medication use (19). Reasons for this gender disparity could also be identified using a prospective cohort design. Furthermore, national surveys are currently not designed to address geographic differences or to consider vulnerable minority populations due to modest sample sizes for sub-populations and the sampling strategy; such analyses would require pooling of multiple survey cycles or different sampling strategies for future surveys.

Anecdotally, in conducting the validation study, I observed that there was a consistent concern from participants that their blood pressure was too low (for example 100/60 mmHg), and they wondered about the benefits of reducing their medication dosages. Obviously, this was not a question that I could address clinically, and I therefore recommended that they speak to their doctor. The concern itself, however, is interesting as it raises question of the benefit of very intensive blood pressure lowering in a general population and could potentially represent a barrier to medication adherence for patients. Another interesting observation was that while many participants mentioned in passing that they were very proud of the things that they had done themselves to improve their blood pressure, many other participants mentioned that their doctor was primarily responsible for controlling their blood pressure and that there was little they could do. The factors influencing this variation in self-efficacy could also be an interesting avenue of research.

Finally, there is a critical need to develop and validate self-reported survey measures, not only to better understand hypertension management, but in general. In this thesis, I showed that even a straight-forward and easy to understand question of blood pressure control resulted in substantial misclassification. Such misclassification can lead to biased findings and inappropriate conclusions on which public health decisions are made. It is my contention that items on national surveys should not be fielded without evidence of their validity and reliability, and that the national survey development process should systematically incorporate validation (i.e., validation should not be conducted in a one-off manner as I did). Although methods have been recently developed to account for the bias and uncertainty introduced by misclassification, this can only be done when evidence of validity exists and is not necessarily a substitute for robust measures.

8.9 Suitability as a doctoral dissertation in Epidemiology

Through this research, I made a number of independent and original contributions to the epidemiology of blood pressure control in Canada and gained new research skills, which I hope in the reader's opinion, demonstrate my ability to undertake independent epidemiologic research and contribute to knowledge surrounding management of hypertension in Canada.

Through critical appraisal and synthesis of the literature, I gained understanding of the epidemiology of blood pressure control, measurement issues in hypertension, the implications of hypertension in diabetes, and behaviour change. The secondary analyses performed within this research allowed me the opportunity to study the descriptive epidemiology of hypertension awareness and control in an efficient way. I tested a novel hypothesis using existing complex survey data and gained an understanding of cross-sectional designs, their strengths and limitations, multistage cluster sampling and its effects on statistical analyses and external validity.

Through the validation study, I gained experience in the development of research protocols and conducting primary data collection. I designed the study, wrote the protocol and research plan, and applied for ethics approval. I conducted the recruitment and conducted all of the in-person interviews and blood pressure measurements, cleaned and analyzed the data, and interpreted the results and prepared them for publication. I became familiar with complex sensitivity analysis techniques and performed a number of complex statistical analyses. I also gained a new appreciation for the effects of misclassification which has admittedly reduced my own previous naiveté and will undoubtedly affect my future research output.

8.10 Conclusions

In summary, my thesis offers the following original contributions to the epidemiology of blood pressure control in Canada. I showed that Canadians with diabetes were less likely to have their blood pressure controlled to target compared to individuals without diabetes. Although people with diabetes were less likely to physically active and more likely to be overweight, they were also more likely to report *trying* to engage in behaviours for blood pressure control. Receipt of advice from a health professional may encourage attempts at behaviour change in people with and without diabetes. Knowledge of blood pressure targets is low in Canada, with less than one in three Canadians with hypertension (28% and 32% with and without diabetes) reporting having discussed a blood pressure target <u>and</u> reporting a blood pressure target in line with clinical practice guidelines. I could not relate receipt of advice, engagement in healthy behaviours, and knowledge of blood pressure targets to blood pressure control, as originally intended, because I showed that 1) the self-reported measure of blood pressure control had low specificity and 2) the method that I intended to use to account for misclassification performs inconsistently in multivariate contexts.

8.11 References

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Table 8-1 Weighted two-by-two table of self-reported blood pressure control by diabetes status based on the 2009 *Survey of Living with Chronic Disease*

	Controlled blood pressure		
Diabetes status	No	Yes	Total
Yes	199,028 (22%)	717,140 (78%)	916,168
No	837,892 (21%)	3,093,228 (79%)	3,931,120

Table 8-2 Weighted two-by-two table of self-reported blood pressure control by diabetes status based on the 2009 *Survey of Living with Chronic Disease*, corrected for misclassification*

	Controlled blood pressure		
Diabetes status	No	Yes	Total
Yes	332,919 (36%)	583,249 (64%)	916,168
No	-86,950 (-2%)	4,018,070 (102%)	3,931,120

* sensitivities of 0.83 and 0.78 and specificities= 0.30 and 0.53 for individuals with and without diabetes

Appendix A

Sensitivity analysis using adjusted blood pressures

In a sensitivity analysis, blood pressures obtained using BpTRU were adjusted to reflect manual mercury sphygmomanometer readings that are typically employed in clinical practice and to allow comparison with previous studies, according to the following validated equations: adjusted systolic = 11.4 + (0.93 x BpTRU systolic) and adjusted diastolic = 15.6 + (0.83 x BpTRU diastolic).

Table A. Among those with hypertension*, proportion who are aware, treated by medication, and controlled, among individuals with and without diabetes, household population aged 20-79 years, Canada 2007-2009.

	With Diabetes (n=176)		**Without Diabetes (n=712) Referent**		**Crude Odds Ratio**		**Adjusted† Odds Ratio**	
	N	**% (95% CI)**	**N**	**% (95% CI)**	**OR**	**(95% CI)**	**OR**	**(95% CI)**
Total hypertensive* population	**176**		**712**					
Aware	155	83.4 (77.8, 89.0)	550	80.2 (74.4, 86.0)	1.2	(0.6, 2.4)	0.8	(0.4, 1.6)
Treated	153	82.3 (77.0, 87.7)	522	76.0 (69.8, 82.2)	1.5	(0.9, 2.5)	1.0	(0.5, 1.8)
Controlled <140/80	126	67.1 (59.0, 75.2)	416	62.2 (57.1, 67.3)	1.2	(0.8, 1.9)	1.0	(0.6, 1.6)
Controlled <130/80	85	45.5 (38.2, 52.9)	243	33.3 (26.8, 39.8)	**1.7**	**(1.2, 2.4)**	1.2	(0.8, 2.0)
Among those treated	**153**		**522**					
Controlled <140/90 mmHg	126	81.5 (73.9, 89.2)	416	81.8 (76.1, 87.5)	1.0	(0.6, 1.5)	1.0	(0.7, 1.5)
Controlled <130/80 mmHg	85	55.3 (47.2, 63.4)	243	43.8 (35.3, 52.3)	**1.6**	**(1.0, 2.5)**	1.3	(0.8, 2.3)

*For individuals with diabetes, systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥80 mmHg, or current use of antihypertensive medication; for individuals without diabetes, systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg, or current use of antihypertensive medication.
† adjusted for: sex, age (continuous), education, income, chronic kidney disease or cardiovascular disease
‡ 95% CI not estimable

Appendix B

Latent trait analysis for variables comprising the clinical advice and healthy behaviour scores

	Factor loadings	
Variable	Factor 1	Factor 2
Clinical Advice for:		
Medication use	0.30	0.78
Salt reduction	0.79	-0.01
Dietary change	0.86	-0.20
Physical activity	0.86	-0.18
Weight control/loss	0.78	-0.18
Correct use of blood pressure monitor	0.41	0.58
Eigenvalue	*2.96*	*1.05*
Cronbach's alpha=0.63		
Final factor - Clinical advice score		
Salt reduction	0.79	
Dietary change	0.88	
Physical activity	0.87	
Weight control/loss	0.80	
Eigenvalue	*2.80*	
Cronbach's alpha=0.73		
Final factor – Healthy behaviour score		
Salt reduction	0.68	
Dietary change	0.77	
Physical activity	0.68	
Weight control/loss	0.64	
Eigenvalue	*2.08*	
Cronbach's alpha=0.64		

Note: Advice for smoking cessation and limiting alcohol consumption were not considered in the composite measure since advice for these behaviours would only apply to the minority of the population who smoked cigarettes or drank more alcohol than recommended since diagnosis. Advice for stress management was not considered because the survey did not contain a corresponding question pertaining to use of stress management strategies.

Appendix C

Ethics approvals

QUEEN'S UNIVERSITY HEALTH SCIENCES AND AFFILIATED TEACHING HOSPITALS ANNUAL RENEWAL

Queen's University, in accordance with the "Tri-Council Policy Statement, 1998" prepared by the Medical Research Council, Natural Sciences and Engineering Research Council of Canada and Social Sciences and Humanities Research Council of Canada requires that research projects involving human subjects be reviewed annually to determine their acceptability on ethical grounds.

A Research Ethics Board composed of:

Dr. A.F. Clark, Emeritus Professor, Department of Biochemistry, Faculty of Health Sciences, Queen's University (Chair)
Dr. H. Abdollah, Professor, Department of Medicine, Queen's University
Dr. R. Brison, Professor, Department of Emergency Medicine, Queen's University
Dr. M. Evans, Community Member
Dr. S. Horgan, Manager, Program Evaluation & Health Services Development, Geriatric Psychiatry Service, Providence Care, Mental Health Services Assistant Professor, Department of Psychiatry
Ms. J. Hudacin, Community Member
Dr. B. Kisilevsky, Professor, School of Nursing, Departments of Psychology and Obstetrics and Gynaecology, Queen's University
Mr. D. McNaughton, Community Member
Ms. P. Newman, Pharmacist, Clinical Care Specialist and Clinical Lead, Quality and Safety, Pharmacy Services, Kingston General Hospital
Ms. S. Rohland, Privacy Officer, ICES-Queen's Health Services Research Facility, Research Associate, Division of Cancer Care and Epidemiology, Queen's Cancer Research Institute
Dr. B. Simchison, Assistant Professor, Department of Anaesthesiology and Perioperative Medicine, Queen's University
Dr. A.N. Singh, WHO Professor in Psychosomatic Medicine and Psychopharmacology Professor of Psychiatry and Pharmacology Chair and Head, Division of Psychopharmacology, Queen's University

has reviewed the request for renewal of Research Ethics Board approval for the project **Knowledge of Blood Pressure Targets and Blood Pressure Control Among Canadians With Hypertension, With and Without Diabetes** as proposed by **Ms. M. Gee** of the **Department of Community Health and Epidemiology** , at **Queen's University** . The approval is renewed for one year, effective **August 02, 2012**. If there are any further amendments or changes to the protocol affecting the participants in this study, it is the responsibility of the principal investigator to notify the Research Ethics Board. Any unexpected serious adverse event occurring locally must be reported within 2 working days or earlier if required by the study sponsor. All other adverse events must be reported within **15** days after becoming aware of the information.

Albert F. Clark

______________________________Date: August 13, 2012
Chair, Research Ethics Board
Renewal 1[X] Renewal 2 [ ] Extension [ ] **Code# EPID-349-11 Romeo file# 6006145**

QUEEN'S UNIVERSITY HEALTH SCIENCES & AFFILIATED TEACHING HOSPITALS RESEARCH ETHICS BOARD-DELEGATED REVIEW

August 02, 2011

Ms. Marianne Gee
Department of Community Health and Epidemiology
Queen's University

Dear Ms. Gee
Study Title: EPID-350-11 Validation of self-reported blood pressure control among people with hypertension attending the Queen's Family Medicine Centre
File # 6006146
Co-Investigators: Dr. I. Janssen, Dr. N. Campbell, Dr. W. Pickett, Dr. R. Birtwhistle

I am writing to acknowledge receipt of your recent ethics submission. We have examined the protocol, questionnaire, invitation letter, recruitment poster, revised letter of information and revised consent form for your project (as stated above) and consider it to be ethically acceptable. This approval is valid for one year from the date of the Chair's signature below. This approval will be reported to the Research Ethics Board. Please attend carefully to the following listing of ethics requirements you must fulfill over the course of your study:

Reporting of Amendments: If there are any changes to your study (e.g. consent, protocol, study procedures, etc.), you must submit an amendment to the Research Ethics Board for approval. Please use event form: HSREB Multi-Use Amendment/Full Board Renewal Form associated with your post review file # **6006146** in your Researcher Portal (https://eservices.queensu.ca/romeo_researcher/)

Reporting of Serious Adverse Events: Any unexpected serious adverse event occurring locally must be reported within 2 working days or earlier if required by the study sponsor. All other serious adverse events must be reported within 15 days after becoming aware of the information. Serious Adverse Event forms are located with your post-review file **6006146** in your Researcher Portal (https://eservices.queensu.ca/romeo_researcher/)

Reporting of Complaints: Any complaints made by participants or persons acting on behalf of participants must be reported to the Research Ethics Board within 7 days of becoming aware of the complaint. Note: All documents supplied to participants must have the contact information for the Research Ethics Board.

Annual Renewal: Prior to the expiration of your approval (which is one year from the date of the Chair's signature below), you will be reminded to submit your renewal form along with any new changes or amendments you wish to make to your study. If there have been no major changes to your protocol, your approval may be renewed for another year.

Yours sincerely,

Albert F. Clark.

Chair, Research Ethics Board
August 02, 2011

Investigators please note that if your trial is registered by the sponsor, you must tale responsibility to ensure that the registration information is accurate and complete

Appendix D

Age, sex and diabetes status distributions of the Canadian population with hypertension and the Queen's Family Health Team source population, selected sample, and participants.

Characteristic	Canadians with hypertension* (%)	Source population N (%)	Sampling rate	Selected Sample N (%)	Participants N (%)	Response rate
Sample 1						
No Diabetes						
Female <65 years	28.6	224 (23.3)	0.254	57 (28.2)	7 (21.2)	0.122
Female >=65 years	25.2	345 (35.9)	0.145	51 (25.2)	10 (30.3)	0.196
Male <65 years	29.4	192 (20.0)	0.307	59 (29.2)	4 (12.1)	0.068
Male >=65 years	16.8	199 (20.7)	0.171	35 (17.3)	12 (36.4)	0.343
Diabetes						
Female <65 years	25.0	70 (19.5)	0.714	50 (24.9)	2 (6.9)	0.04
Female >=65 years	26.2	89 (24.8)	0.584	52 (25.9)	7 (24.1)	0.135
Male <65 years	29.5	108 (30.1)	0.546	59 (29.4)	7 (24.1)	0.119
Male >=65 years	19.4	92 (25.6)	0.424	40 (19.9)	13 (44.8)	0.325
Sample 2						
No Diabetes						
Female <65 years	28.6	162 (21.0)	0.395	64 (28.2)	11 (19.0)	0.172
Female >=65 years	25.2	299 (38.8)	0.191	57 (25.1)	22 (37.9)	0.386
Male <65 years	29.4	134 (17.4)	0.492	68 (30.0)	13 (22.4)	0.191
Male >=65 years	16.8	175 (22.7)	0.217	38 (16.7)	12 (20.7)	0.316
Diabetes						
Female <65	25.0	23 (13.1)	1.0	23 (13.1)	3 (8.3)	0.130
Female >=65	26.2	44 (25.1)	1.0	44 (25.1)	8 (22.2)	0.182
Male <65	29.5	54 (30.8)	1.0	54 (30.8)	8 (22.2)	0.148
Male >=65	19.4	54 (30.8)	1.0	54 (30.8)	17 (47.2)	0.314

*household population age 20+ with diagnosed hypertension, according to the 2009 *Survey on Living with Chronic Disease in Canada*

Appendix E

Invitation letter

DEPARTMENT OF FAMILY MEDICINE
Family Medicine Centre
220 Bagot Street, P.O. Bag 8888
Kingston, Ontario, Canada K7L5E9
Date
Dear [Name of eligible participant],

You are being invited to participate in a research study to determine the usefulness of a questionnaire in understanding management of high blood pressure.

The study involves a 15 to 20 minute clinic visit at the Queen's Family Health Team, during which you would answer a short series of questions and have your blood pressure measured. This research is being conducted in association with the Queen's Family Health Team, with direction from Dr. Richard Birtwhistle, Dr. William Pickett, Dr. Ian Janssen, and Ms. Marianne Gee. Thank you for taking the time to consider participating.

If you are interested in participating or would like more information, please call or email:
Marianne Gee
Study coordinator
Clinical Research Centre, Kingston General Hospital
[redacted]
Sincerely,

Queen's Family Health Team
Department of Family Medicine   page 1 of 2

What is the purpose of the research?

The purpose of this study is to determine the usefulness of a survey questionnaire in understanding management of high blood pressure. While you may not benefit directly by participating, results may improve the understanding of high blood pressure and may benefit people in the future.

What does participation involve?

Should you choose to participate, you will be asked a series of questions and have your blood pressure measured using an automated blood pressure monitor. Your visit will take approximately 15 to 20 minutes. Your medical chart will also be reviewed for information related to your blood pressure. You will be reimbursed for parking.

Your participation in this study is voluntary. Should you choose to participate, you can withdraw at any time and the information collected will be destroyed.

How will my privacy be protected?

Should you choose to participate, all information obtained during the course of the study will remain strictly confidential and your anonymity will be protected at all times. Your name will only be collected on the consent form, which will be kept separate from the information collected. Your information will be stored in locked files and will be available only to the study investigators. You will not be identified in any publication or report.

Appendix F

Reminder postcard sent to selected participants

Reminder: Queen's Blood Pressure Study Date

In January, a letter was mailed to you inviting you to participate in a research study to determine the usefulness of a questionnaire in understanding management of high blood pressure. Your name was drawn in a random sample of patients of the Queen's Family Health Team.

If you have already participated in the study, please accept our sincere thanks. If not, please consider participating by calling/emailing **Marianne Gee at** [redacted]. Because the invitation was sent to only a small, but representative, sample of individuals, it is important that you be included if the results of the research are to be valid in people with high blood pressure.

If by some chance you did not receive the original invitation letter, or it was misplaced, please call or email me for more information.

Sincerely,

Marianne Gee
Study Coordinator
Queen's Blood Pressure Study
[redacted]

Appendix G

Information sheet and consent form

Project: EPID-350-11 Validation of self-reported blood pressure control among people with hypertension attending the Queen's Family Medicine Centre

Investigators: M Gee (PhD candidate), Dr. I Janssen, Dr. W Pickett, Dr. R Birtwhistle

INFORMATION SHEET

What is the purpose of the research?

The purpose of this study is to determine the usefulness of a survey questionnaire in understanding management of high blood pressure.

While you may not benefit directly from this study, results may improve the understanding of high blood pressure and may benefit people in the future.

Who can participate?

You can participate in this research if you are:

20 years of age or older

Have been diagnosed with high blood pressure

You will not be able to participate if:

You are currently pregnant

Your blood pressure cannot be measured due to a medical condition affecting both arms.

What does participation involve?

You will be asked a series of questions and have your blood pressure measured using an automated blood pressure monitor. This will take approximately 15 to 20 minutes. Your medical chart will also be reviewed for information related to your blood pressure. You will be reimbursed for parking.

How will my privacy be protected?

All information obtained during the course of this study is strictly confidential and your anonymity will be protected at all times. Your name will only be collected on the consent form, which will be kept separate from the information that we collect today. Your information will be stored in locked files and will be available only to the study investigators. You will not be identified in any publication or report.

What if I decide I don't want to participate?

Your participation in this study is voluntary. You may withdraw from this study at any time and the information we collect today will be destroyed. Should you choose to withdraw, your withdrawal will not affect your future medical care with your physician or this clinic. By signing the consent form, you do not waive your legal rights nor release the investigator(s) and sponsors from their legal and professional responsibilities.

What if I have more questions?

Ms. Marianne Gee will read through this consent form with you and describe procedures in detail and answer any questions you may have. This study has been reviewed for ethical compliance by the Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board.

If at any time I have further questions or problems, I can contact:

Dr. Ian Janssen

Queen's University, School of Health Studies

[redacted]

If I have questions about my rights as a research subject I can contact:

Dr. Albert Clark

Chair, Queen's University Health Sciences Research Ethics Board

[redacted]

CONSENT FORM

SUBJECT STATEMENT:

I have read and understand the information sheet for this study.

I have had the purposes, procedures and technical language of this study explained to me.

I have been given sufficient time to consider the above information and to seek advice if I chose to do so.

I have had the opportunity to ask questions which have been answered to my satisfaction.

I am voluntarily signing this form.

I will receive a copy of this consent form for my information.

If at any time I have further questions or problems, I can contact:

Dr. Ian Janssen

Queen's University, School of Health Studies

[redacted]

If I have questions about my rights as a research subject I can contact:

Dr. Albert Clark

Chair, Queen's University Health Sciences Research Ethics Board

[redacted]

SIGNATURE SECTION:

By signing this consent form, I am indicating that I agree to participate in this study.

_________________________ __________________

Signature of Patient Date

_________________________ __________________

Name (please print)

ID:

STATEMENT OF INVESTIGATOR:

I, or one of my colleagues, have carefully explained to the subject the nature of the above research study. I certify that, to the best of my knowledge, the subject understands clearly the nature of the study and demands, benefits, and risks involved to participants in this study.

____________________________ __________________

Signature of Investigator Date

Appendix H

In person interview: Short version of the 2009 *Survey on Living with Chronic Disease in Canada Hypertension Questionnaire*

PATIENT ID: ___________________________

Sections in bold are read to the participant

Thank you for taking the time to consider participating in the study.

The purpose of this study is to determine the usefulness of a survey questionnaire in understanding management of blood pressure.

Your answers will be kept strictly confidential and used only for statistical purposes. Participation is voluntary.

Before we start, we need to review the information sheet that I have given you. Please take a few minutes to read through it. If you have any questions, I can answer them for you.

Here is the consent form for participation in today's study. Please read the form carefully and please sign it if you are willing to participate.

C01 Consent form signed

❑1 Yes (Go to C03)

❑2 No (Go to C02)

C03 **Thank you for agreeing to participate in the study.**

Sex ❑1 Male

❑2 Female

I'd like to start by asking you about your high blood pressure and about some chronic health conditions which you may have.

Q01 **How old were you when you were first diagnosed with high blood pressure?**
If necessary, ask (**Do you know the approximate age in years?**).

_ _ _ _ Age in years ❑.D Don't Know ❑.E Refused

AGE **What is your current age in years?**

_ _ _ _ Age in years

Q02 **In general, do you consider your blood pressure to be:**
INTERVIEWER: Read categories to respondent.

❑1 **...well-controlled (normal, fine, ok)?**

❑2 **...borderline?**

❑3 **...high?**

❑4 **...low?**

❑.D Don't Know

❑.E Refused

Q03 **Currently, are you taking any prescription medications for high blood pressure?**
INTERVIEWER: Include over-the-counter medications such as low-dose aspirin if the medication was prescribed by a doctor or health professional.

❑1 Yes

❑2 No (Go to Q05)

❑.D Don't Know (Go to Q05)

❑.E Refused (Go to Q05)

Q04 **Currently, how many different types of prescription medications are you taking for your high blood pressure?**
INTERVIEWER: Read categories to respondent. Include medications taken for hypertension.

❑1 **One**

❑2 **Two**

❑3 **Three**

❑4 **Four or more**

❑.D Don't Know

❑.E Refused

❑.F Not applicable

Q05 **Have you ever been diagnosed with diabetes?**

❑1 Yes

❑2 No (Go to Q08)

❑.D Don't Know

❑.E Refused

If male go to Q08

Q06 **Were you pregnant when you were first diagnosed with diabetes?**

❑1 Yes

❑2 No

❑.F Not applicable

Q07 **Other than during pregnancy, has a health professional ever told you that you have diabetes?**

❑1 Yes

❑2 No

❑.F Not applicable

Now I'm going to ask some questions about having your blood pressure measured by a health professional.

Q08 **When was the last time you had your blood pressure measured by a health professional? Was it:** INTERVIEWER: Read categories to respondent.

❑ **1 … less than 1 month ago?**

❑ **2 … 1 month to less than 3 months ago?**

❑ **3 … 3 months to less than 6 months ago?**

❑ **4 … 6 months to less than 1 year ago?**

❑ **5 … 1 year to less than 2 years ago?**

❑ **6 … 2 or more years ago?**

❑ 7 Never had blood pressure measured by a health professional (Go to Q10)

❑.D Don't Know (Go to Q10)

❑.E Refused (Go to Q10)

Q09 **The last time your blood pressure was measured by a health professional, were you told that your blood pressure was:** INTERVIEWER: Read categories to respondent.

❑ **1 … well-controlled (normal, fine, ok)?**

❑ **2 … borderline?**

❑ **3 … high?**

❑ **4 … low?**

❑ 5 Health professional did not say

❑.D Don't Know

❑.E Refused

❑.F Not applicable

Q10 **Has a health professional ever discussed a target rate for your blood pressure, that is, the blood pressure level that is best for you?**

❑1 Yes

❑2 No

❑.D Don't Know

❑.E Refused

Q11 **Have you ever received information on a target rate for your blood pressure from another source (such as a pamphlet, television, radio, newspaper, or the internet)?**

❑1 Yes

❑2 No

❑.D Don't Know

❑.E Refused

If Q10=2 and Q11=2 then go to 15)

Q12 **What is your target systolic pressure (that is the top or higher number)?**

❑1 Respondent provided exact value(Go to Q12a)

❑2 Respondent provided a range (Go to Q12b)

❑.D Don't Know (Go to Q13)

❑.E Refused (Go to Q13)

❑.F Not applicable

Q12a *Enter the systolic value provided by respondent.*

_______ mmHg

(MIN: 1) (MAX: 300)

Go to XBMH_Q11

❑.F Not applicable

Q12b *Enter the range of systolic values provided by respondent. Do not enter more than one range. If respondent gives a range that exceeds a single category (for example, "between 120 and 140") probe for the range that best describes the blood pressure value.*

❑1 Less than 100

❑2 Less than 120

❑3 Less than 130

❑4 Less than 140

❑5 Between 100 and 109

❑6 Between 110 and 119

❑7 Between 120 and 129

❑8 Between 130 and 139

❑9 Between 140 and 149

❑10 Between 150 and 159

❑11 Between 160 and 169

❑12 Between 170 and 179

❑13 180 or over

❑.F Not applicable

Q13 **What is your target diastolic pressure (that is, the bottom or lower number)?**

❑1 Respondent provided exact value(Go to Q13a)

❑2 Respondent provided a range (Go to Q13b)

❑.D Don’t Know (Go to Q14)

❑.E Refused (Go to Q14)

❑.F Not applicable

Q13a *Enter the diastolic value provided by respondent.*

_______ mmHg
(MIN: 1) (MAX: 150)
Go to XBMH_Q14
❑.F Not applicable

Q13b *Enter the range of diastolic values provided by respondent. Do not enter more than one range. If respondent gives a range that exceeds a single category (for example, "between 60 and 80") probe for the range that best describes the blood pressure value.*

❑1 Less than 80

❑2 Less than 90

❑3 Less than 50

❏4 Between 50 and 59

❏5 Between 60 and 69

❏6 Between 70 and 79

❏7 Between 80 and 89

❏8 Between 90 and 99

❏9 Between 100 and 109

❏10 Between 110 and 119

❏11 Between 120 or over

❏.F Not applicable

Q14 **Do you feel that you have a plan to control your blood pressure?**

❏1 Yes

❏2 No

❏.D Don't Know

❏.E Refused

The next few questions are about blood pressure monitoring you may do yourself outside of a health professional's office or medical clinic.

Q15 **Do you monitor you own blood pressure outside of a health professional's office or medical clinic?**

❏1 Yes

❏2 No (go to Q17)

❏.D Don't Know

❏.E Refused

Q16 **How often do you monitor your own blood pressure outside of a health professional's office or medical clinic?**

❏1 **Daily**

❑2 **Weekly**

❑3 **Monthly**

❑4 **Three to four times a year**

❑5 **Once a year**

❑6 **Less than once a year**

❑.D Don’t know

❑.E Refused

❑.F Not applicable

Q17 **Has a doctor or other health professional ever shown you how to correctly use a blood pressure measurement device?**

❑1 Yes

❑2 No

❑.D Don’t Know

❑.E Refused

❑.F Not applicable

Where do you measure your own blood pressure?
INTERVIEWER: Mark all that apply.

Q18a At home

❑1 Yes ❑2 No ❑.D DK ❑.E Ref ❑.F NA

Q18b Pharmacy

❑1 Yes ❑2 No ❑.D DK ❑.E Ref ❑.F NA

Q18c Workplace

❑1 Yes ❑2 No ❑.D DK ❑.E Ref ❑.F NA

Q18d Gym or fitness facility

❑1 Yes ❑2 No ❑.D DK ❑.E Ref ❑.F NA

Q18e Other

❑1 Yes ❑2 No ❑.D DK ❑.E Ref ❑.F NA

The next questions are about things that may affect your blood pressure readings today.

Q19 **Have you smoked cigarettes or used other tobacco or nicotine products during the past 2 hours?**

❑1 Yes

❑2 No

❑.D Don’t Know ❑.E Refused

Q20 **Have you consumed coffee, tea or other caffeinated drinks in the past 2 hours?**

❑1 Yes

❑2 No

❑.D Don’t Know ❑.E Refused

Q21 **Have you exercised or participated in physical activity in the past 2 hours?**

❑1 Yes

❑2 No

❑.D Don’t Know ❑.E Refused

That concludes the interview portion and now I will take your blood pressure using an automated blood pressure cuff. During this test you will need to sit with your feet flat on the floor with your back against the back rest of the chair, and have your right arm straight on the table, palm facing down.

Before taking the six measurements, the respondent will rest for a period of five minutes.

Instruction: Measure arm circumference. Select the appropriate cuff size based on arm circumference, secure it on the right arm and ensure the respondent is in the correct seated position.

The blood pressure cuff will inflate automatically once every minute, applying pressure to your arm. A total of six measures will be taken. I will stay in the room for the first measurement but will leave the room for all others. You should not move or talk during the test, and you need to keep both feet flat on the floor. It is important that you stay relaxed to ensure we get good results. Do you have any questions before we begin?

Instruction: Answer any questions as thoroughly as possible.

Now I will start the machine.

Instruction: Press <Start> on the BPTru screen. Check that the BPTru collects the first measurement properly. Allow the BPTru to collect six measurements. Lock the fields containing the data from the BPTru. Save and record the measurements.

First	SBP1: ____mmHg	DBP1:____ mmHg	Pulse1: _______bpm
2nd	SBP2: ____mmHg	DBP1:____ mmHg	Pulse2: _______bpm
3rd	SBP3: ____mmHg	DBP1:____ mmHg	Pulse3: _______bpm
4th	SBP4: ____mmHg	DBP1:____ mmHg	Pulse4: _______bpm
5th	SBP5: ____mmHg	DBP1:____ mmHg	Pulse5: _______bpm
Average	SBP_AVG: ____mmHg	DBP_AVG:____ mmHg	
	Pulse_AVG: ___bpm		

If errors in any of the measurements:

There were too many problems with that set of measurements, so we will do the test again. I will retake your blood pressure and heart rate.

Your average blood pressure today was [average systolic BP]/[average diastolic BP] mmHg. Refer to statement for reporting back to respondent
This concludes the interview. Your participation is greatly appreciated. Thank you for your time.

Blood Pressure
Reporting protocol

Feedback will be provided to all respondents at the conclusion of the clinic visit. This will include resting pulse and blood pressure.
Findings will be reported according to Table 1 taken from the guidelines for measurement of blood pressure, follow-up, and lifestyle counselling (Abbott, 1994).

Table 1. Adult blood pressure values.Systolic	**Diastolic**					
	<85	**85-89**	**90-99**	**100-109**	**110-119**	**≥120**
<130	**1**	**1**	**2**	**3**	**4**	**5**
130-139	**1**	**1**	**2**	**3**	**4**	**5**
140-159	**2**	**2**	**2**	**3**	**4**	**5**
160-179	**3**	**3**	**3**	**3**	**4**	**5**
180-199	**4**	**4**	**4**	**4**	**4**	**5**
≥200	**5**	**5**	**5**	**5**	**5**	**5**

Statement for reporting back to respondent

1. Your blood pressure today is well-controlled. Hypertension Canada recommends that people with hypertension have their blood pressure checked at all appropriate doctor's visits and at least once per year.

2. Your blood pressure today is borderline high. You may want to see your doctor within the next two months to have your blood pressure rechecked.

3. Your blood pressure is moderately high. You may want to see your doctor within the next month to have your blood pressure rechecked.

4. Your blood pressure is high. **You should see your doctor within the next week to have your blood pressure rechecked.**

5. Your blood pressure today is very high. **You should see your doctor or one of the clinic nurses today.**

Appendix I

Chart abstraction form

Demographic number			
	Year	Month	Day
Date of interview			

BP Measurements in year prior to interview:

Visit	Year	Month	Day	SBP	DBP
1					
2					
3					
4					
5					
6					
7					
8					

Antihypertensive medications

#	ATC	NAME
1		
2		
3		
4		
5		
6		
7		

Comorbidities

Diabetes	1 - Yes	0 - No
Chronic kidney disease	1 - Yes	0 - No
Edema	1 - Yes	0 - No
Heart Failure	1 - Yes	0 - No
Arrhythmia	1 - Yes	0 - No
Migraine	1 - Yes	0 - No
Angina	1 - Yes	0 - No
Myocardial infarction	1 - Yes	0 - No

Appendix J

Anatomical Therapeutic Chemical [ATC] classification of antihypertensive medications based on substance and trade names.

ATC Code	Substance name (*trade names**)
MISCELLANEOUS ANTIHYPERTENSIVES	
C02AC01	clonidine (*catapres)*
C02CA01	prazosin *(minipress, prazosin, prazo)*
C02CA04	doxazosin *(cardura)*
C02DB02	hydralazine *(apresoline, hydral, hylazin)*
DIURETICS	
C03AA03	hydrochlorothiazide *(apo-hydro, codema, diuchlor, hydrodiuril, urozide)*
C03BA04	chlortalidone *(hygroton)*
C03BA08	metolazone *(zoroxolyn)*
C03BA11	indapamide *(lozide)*
C03CA01	furosemide *(furoside, lasix, uritol)*
C03DA01	spironolactone *(aldactone)*
C03EA01	hydrochlorothiazide and potassium-sparing agents *(aldactazide, ami-hydro, amiloride, amilzide, dyazide, moduret, novamilor, riva-zide, spironolactone-hctz, spirozide, thiazide, triamterene, triazide)*
BETA BLOCKING AGENTS	
C07AA05	propranolol *(inderal, novo-pranol, propanolo hydrochloride)*
C07AA07	sotalol *(linsotalol, rylosol, sotacor, sotamol)*
C07AA12	nadolol *(apo-nadol, corgard)*
C07AB02	metoprolol *(betaloc, lopresor)*
C07AB03	atenolol *(tenormin)*
C07AB04	acebutolol *(monitan, rhotral, sectra,)*
C07AB07	bisoprolol *(monocor, mylan)*
C07AG01	labetalol *(trandate)*
C07AG02	carvedilol *(coreg)*
CALCIUM CHANNEL BLOCKERS	
C08CA01	amlodipine *(norvasc)*
C08CA02	felodipine *(plendil, renedil)*
C08CA05	nifedipine *(adalat, nifed)*
C08DA01	verapamil *(apo-verap, covera, isoptin, veramil, verelan)*
C08DB01	diltiazem *(cardizem, diltiaz, tiazac)*

ATC Code	**Substance name (*trade names**)**
ACE INHIBITORS	
C09AA01	captopril *(capto, capoten, captril)*
C09AA02	enalapril *(vasotec)*
C09AA03	lisinopril *(prinivil, zestril)*
C09AA04	perindopril *(coversyl)*
C09AA05	ramipril *(altace)*
C09AA06	quinapril *(accupril)*
C09AA07	benazepril *(lotensin)*
C09AA08	cilazapril *(inhibace)*
C09AA09	fosinopril *(monopril)*
C09AA10	trandolapril *(mavik)*
ANGIOTENSIN RECEPTOR BLOCKERS	
C09CA01	losartan *(cozaar)*
C09CA02	eprosartan *(tevetan)*
C09CA03	valsartan *(diovan)*
C09CA04	irbesartan *(avapro)*
C09CA06	candesartan *(atacand)*
C09CA07	telmisartan *(micardis)*
RENIN INHIBITORS	
C09XA01	remikiren
C09XA02	aliskiren *(rasilez)*
TWO CLASS COMBINATIONS	
C02LA01	reserpine and diuretics *(hydropres, ser-a-pes)*
C07BA12	nadolol and thiazides *(corzide)*
C07CB03	atenolol and other diuretics *(apo-atenidone, tenoretic)*
C09BA02	enalapril and diuretics *(vaseretic)*
C09BA03	lisinopril and diuretics *(lisinopril, prinzide, zestoretic)*
C09BA04	perindopril and diuretics *(coversyl plus)*
C09BA05	ramipril and diuretics *(altace hct, ramipril-hctz)*
C09BA06	quinapril and diuretics *(accuretic)*
C09BB05	ramipril and felodipine *(altace plus felodipine)*
C09DA01	losartan and diuretics *(hyzaar)*
C09DA02	eprosartan and diuretics *(tevetan plus)*
C09DA03	valsartan and diuretics *(diovan-hct, valsartan-hct)*
C09DA04	irbesartan and diuretics *(avalide)*
C09DA06	candesartan and diuretics *(atacand)*
C09DA07	telmisartan and diuretics *(micardis plus, telmisartan-hctz)*
C09XA52	aliskiren and hydrochlorothiazide *(rasilez hct)*
C09XA53	aliskiren and amlodipine
C09XA54	aliskiren, amlodipine and hydrochlorothiazide

*Trade names determined using the Health Canada Drug Product Database.

Appendix K

Comparison between self-reported blood pressure control and blood pressure control on the day of interview (BPTru) using a 135/85 mmHg threshold in participants with hypertension attending the Queen's Family Health Team, Kingston, Ontario, Canada, 2012, overall, and by diabetes status, gender and age.

	TP	**FP**	**TN**	**FN**	**Se (95% CI)**	**Sp (95% CI)**	**PPV (95% CI)**	**NPV (95 % CI)**
Overall*	95	28	19	16	84 (77-90)	42 (29-55)	75 (68-83)	55 (40-70)
By Diabetes status								
No	51	18	14	11	82 (70-91)	44 (26-62)	74 (62-84)	56 (35-76)
Yes	44	10	5	5	90 (45-97)	33 (12-62)	81 (68-91)	50 (19-81)
By Gender*								
Men	52	20	10	5	90 (82-98)	36 (20-55)	70 (57-80)	68 (47-90)
Women	43	8	9	11	79 (69-89)	51 (30-72)	82 (72-92)	46 (26-66)
By Age (years)*								
<65	26	10	9	9	71 (57-85)	53 (32-74)	74 (57-87)	50 (30-70)
≥65	67	17	8	7	90 (83-97)	30 (14-47)	77 (68-86)	54 (30-78)

TP – true positives; FP – false positives; TN – true negatives; FN – false negatives; Se – sensitivity; Sp – specificity; PPV – positive predictive value; NPV – negative predictive value

*estimates weighted to reflect the distribution of diagnosed diabetes (22.7%) in the 2006/07 Canadian population diagnosed with hypertension(73)

Appendix L

Comparison between self-reported blood pressure control and blood pressure control on the day of interview (BPTru) with blood pressures adjusted to reflect sphygmomanometry† in participants with hypertension attending the Queen's Family Health Team, Kingston, Ontario, Canada, 2012, overall, and by diabetes status, gender and age.

	TP	FP	TN	FN	Se (95% CI)	Sp (95% CI)	PPV (95% CI)	NPV (95 % CI)
Overall*	88	35	17	18	82 (74-88)	40 (27-54)	77 (69-84)	48 (33-63)
By Diabetes status								
No	56	13	12	13	81 (70-90)	48 (28-69)	81 (70-90)	48 (28-69)
Yes	32	22	5	5	86 (71-95)	18 (4-38)	59 (45-72)	50 (19-81)
By Gender*								
Men	45	27	8	7	85 (75-94)	29 (13-44)	67 (56-78)	51 (28-75)
Women	43	8	9	11	80 (70-89)	59 (37-81)	87 (79-95)	46 (26-66)
By Age (years)*								
<65	26	10	8	10	70 (55-83)	59 (33-82)	82 (66-92)	43 (23-66)
≥65	60	24	8	7	90 (83-97)	29 (13-45)	75 (65-84)	54 (30-78)

TP – true positives; FP – false positives; TN – true negatives; FN – false negatives; Se – sensitivity; Sp – specificity; PPV – positive predictive value; NPV – negative predictive value

† adjusted systolic blood pressure = 11.4 + (0.93 x BpTRU systolic blood pressure) and adjusted diastolic blood pressure = 15.6 + (0.83 x BpTRU diastolic blood pressure).

*estimates weighted to reflect the distribution of diagnosed diabetes (22.7%) in the 2006/07 Canadian population diagnosed with hypertension(73)

Appendix M

Self-reported blood pressure control compared to chart-abstracted blood pressure control the last time it was measured in the clinic and over the previous year.

	TP	FP	TN	FN	Se (95% CI)	Sp (95% CI)	PPV (95% CI)	NPV (95 % CI)
Compared to blood pressure control the last time measured in the clinic								
Overall*	68	55	23	12	84 (75-91)	35 (24-45)	60 (52-69)	65 (50-79)
By Diabetes status								
No	45	24	16	9	83 (70-92)	40 (25-57)	65 (53-76)	64 (42-82)
Yes	23	31	7	3	88 (70-98)	18 (8-34)	43 (29-57)	70 (35-93)
By Gender*								
Men	38	34	11	4	89 (76-96)	31 (17-45)	59 (47-71)	71 (50-92)
Women	30	21	12	8	79 (65-89)	39 (23-54)	62 (50-74)	60 (39-79)
By Age (years)*								
<65	25	11	12	6	79 (66-92)	64 (44-83)	78 (64-91)	65 (43-84)
≥65	42	42	10	5	90 (82-98)	22 (11-35)	54 (44-65)	67 (44-89)
Compared to average blood pressure control over previous year								
Overall*	71	52	25	10	86 (79-93)	61 (28-50)	86 (57-74)	67 (53-81)
By Diabetes status								
No	50	19	16	9	85 (73-93)	46 (29-63)	72 (60-83)	64 (42-82)
Yes	21	33	9	1	95 (77-100)	21 (10-37)	39 (26-53)	90 (56-100)
By Gender*								
Men	37	35	11	4	87 (77-97)	29 (15-43)	59 (47-70)	66 (43-88)
Women	34	17	14	6	85 (72-93)	51 (34-68)	73 (62-84)	32 (47-85)
By Age (years)*								
<65	29	7	12	6	78 (66-91)	72 (52-92)	86 (74-97)	61 (38-80)
≥65	42	42	11	4	91 (81-97)	25 (12-37)	60 (49-70)	70 (48-92)

TP – true positives; FP – false positives; TN – true negatives; FN – false negatives; Se – sensitivity; Sp – specificity; PPV – positive predictive value; NPV – negative predictive value

*estimates weighted to reflect the distribution of diagnosed diabetes (22.7%) in the 2006/07 Canadian population diagnosed with hypertension (73)

Appendix N

Comparison of Queen's Family Health Team (age 20+), Survey on Living with Chronic Disease in Canada (age 20+), and Canadian Health Measures Survey (age 20-79) samples.

	No Diabetes			Diabetes		
Characteristics	QFHT* %	SLCDC %	CHMS %	QFHT %	SLCDC %	CHMS %
Age (mean – years)	68	65	62	70	67	50
Female (%)	54	54	49	51	51	
Systolic blood pressure (mean – mmHg)	126	-	126	121	-	123
Diastolic blood pressure (mean – mmHg)	74	-	75	69	-	69
Blood pressure control (% - Self-reported)	70	79	-	79	78	-
Blood pressure control (% - Measured)	77	-	81	67	-	63
Time since diagnosis (years)						
≤ 2	6	17	-	3	11	-
3 – 5	17	22	-	4	16	-
6 – 9	11	19	-	12	16	-
10+	54	42	-	81	57	-
Monitors blood pressure at home at least weekly (%)	15	25	-	11	30	-
Could report recommended blood pressure targets	58	32		52	28	
Blood pressure measurement in previous 6 months (%)	91	84	-	98	93	-
Self-reported number of antihypertensive medications (%)						
0	12	21	-	7	8	-
1	47	50	-	38	56	-
2	27	21	-	38	24	-
3+	13	8	-	17	12	-
Number of antihypertensive medications (%)						
0	11	-	16	4	-	2
1	51	-	35	23	-	39
2	25	-	37	47	-	29
3+	14	-	12	26	-	29

'-' Not applicable because not measured * % weighted to reflect the sex and age (<65 vs ≥ 65 years) distribution of Canadians diagnosed with diabetes from the 2009 *Survey on Living with Chronic Disease in Canada*

Appendix O

Multivariate associations between covariates and objectively-measured and self-reported overweight/obesity and physical inactivity

	Overweight/obesity		Physical inactivity	
	Objectively-measured OR (95% CI)	**Self-reported OR (95% CI)**	**Objectively-measured OR (95% CI)**	**Self-reported OR (95% CI)**
Body mass index (kg/m2 - continuous)	--	--	1.08 (1.05-1.11)	1.03 (1.01-1.05)
Moderate-to-vigorous physical activity (min/week – continuous)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	--	--
Age and sex				
Male, 20-59 years	Referent	Referent	Referent	Referent
Female, 20-59 years	0.45 (0.36-0.56)	0.48 (0.38-0.62)	1.39 (1.03-1.86)	1.09 (0.85-1.40)
Male, 60-79 years	1.17 (0.91-1.52)	1.08 (0.85-1.36)	1.01 (0.70-1.46)	0.73 (0.52-1.02)
Female, 60-79years	0.82 (0.59-1.13)	0.70 (0.51-0.96)	1.65 (1.07-2.54)	0.84 (0.57-1.23)
Has diabetes	3.01 (1.97-4.58)	2.87 (1.88-4.40)	2.83 (1.34-5.94)	1.09 (0.78-1.51)
Non-white race	0.61 (0.45-0.82)	0.50 (0.37-0.66)	0.85 (0.54-1.35)	1.60 (1.15-2.22)
Highest level of education				
Postsecondary graduate	--	--	Referent	Referent
Some postsecondary education			0.87 (0.54-1.38)	1.28 (0.87-1.87)
High school graduate			1.07 (0.72-1.58)	1.30 (1.03-1.65)
Less than high school			1.21 (0.80-1.83)	1.55 (0.98-2.46)
Total household income				
≥ $80,000	Referent	Referent	--	--
$50,000-$79,999	1.02 (0.72-1.43)	0.98 (0.73-1.31)		
$30,000-$49,999	0.86 (0.67-1.09)	0.85 (0.64-1.12)		
$0 - $29,999	0.75 (0.53-1.06)	0.78 (0.58-1.05)		
High alcohol consumption	--	--	1.05 (0.68-1.63)	1.10 (0.82-1.48)
Self-reported smoking				
Never smoker	Referent	Referent	Referent	Referent
Former smoker	1.38 (1.09-1.74)	1.32 (1.05-1.67)	0.94 (0.72-1.23)	0.86 (0.29-0.83)
Occasional smoker	1.37 (0.71-2.65)	1.19 (0.62-2.29)	0.46 (0.25-0.84)	0.49 (0.29-0.83)
Daily smoker	0.79 (0.57-1.11)	0.78 (0.55-1.09)	1.81 (1.21-2.72)	1.53 (1.10-2.13)
Salt always added to food	--	--	1.30 (1.04-1.64)	1.42 (1.12-1.78)

'- -' variable not retained in final model