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Original Article

Prevalence, Patient Awareness, Treatment, and Control of Hypertension in Canadian Adults With Common Comorbidities

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ABSTRACT

Background: Whether certain medical conditions are associated with blood pressure (BP) treatment and control is unclear.

Methods: Using the Canadian Health Measures Survey (2007-2019), BP was assessed according to the presence of selected comorbidities, including prior heart attack or stroke, dyslipidemia, chronic kidney disease, diabetes mellitus, obstructive sleep apnea, and overweight or obesity.

Results: A total of 5,841,453 people, representing 23.0% (95% confidence interval [CI] 21.7%-24.2%) of Canadian adults, were hypertensive. The adjusted odds ratio (aOR) of having hypertension treated and controlled was higher in people with the following conditions, as compared to people without these conditions: a prior heart attack or stroke (aOR 3.15; 95% CI 2.31-4.31); dyslipidemia (aOR 2.51; 95% CI 1.96-3.21); obstructive sleep apnea (aOR 1.95; 95% CI 1.19-3.21); overweight or obesity (aOR 1.51; 95% CI 1.18-1.94); chronic kidney disease (aOR 1.49; 95% CI 1.13-1.95); and diabetes (aOR 1.44; 95% CI 1.12-1.86). Individuals without any of these comorbidities were less likely to have BP that is treated and controlled (aOR 0.34; 95% CI 0.25-0.48). Moreover, the prevalence of BP treatment and control was low among many people without prior heart attack or stroke, even those with a moderate (aOR 0.25; 95% CI 0.17-0.37) or high (aOR

RÉSUMÉ

Contexte : Il n'est pas clair si certaines conditions médicales sont associées au traitement et au contrôle de la pression artérielle (PA).

Méthodes : À l'aide de l'Enquête canadienne sur les mesures de la santé (2007-2019), la PA a été évaluée en fonction de la présence de comorbidités sélectionnées, y compris les antécédents de crise cardiaque ou d'accident vasculaire cérébral (AVC), la dyslipidémie, l'insuffisance rénale chronique, le diabète sucré, l'apnée obstructive du sommeil et le surpoids ou l'obésité.

Résultats : Au total, 5 841 453 individus, représentant 23,0 % (intervalle de confiance [IC] à 95 % 21,7%-24,2 %) des adultes canadiens, étaient hypertendus. Le rapport de cotes ajusté (RCa) pour le traitement et le contrôle de l'hypertension était plus élevé chez les personnes présentant les conditions suivantes, par rapport aux personnes ne présentant pas ces conditions: une crise cardiaque ou un AVC antérieur (RCa 3,15; IC à 95 % 2,31-4,31); dyslipidémie (RCa 2,51; IC à 95 % 1,96-3,21); apnée obstructive du sommeil (RCa 1,95; IC à 95 % 1,19-3,21); surpoids ou obésité (RCa 1,51; IC à 95 % 1,18-1,94); maladie rénale chronique (RCa 1,49; IC à 95 % 1,13-1,95); et diabète (RCa 1,44; IC à 95 % 1,12-1,6). Les personnes ne présentant aucune de ces comorbidités étaient moins susceptibles d'avoir une PA traitée et contrôlée (RCa 0,34; IC à 95 % 0,25-0,48). De plus, la prévalence du traitement et du contrôle

Hypertension is of major clinical and public health importance because of its high prevalence and strong link with numerous adverse health outcomes.[1-3] Controlling blood pressure (BP) has been proven to be highly effective in preventing stroke, heart attack, heart failure, and premature death in both the young and old.[4,5] Even so, disturbing data from numerous sources indicate a general decline in both patient awareness and control of hypertension in Canada and the US in recent years, leading to concerns that this could lead to a rise in preventable disability and death.[6-8]

Consequently, in the past few years, urgent calls have been made for renewed national interest in improving BP control, government reinvestment in hypertension care, and re-engagement among the clinical and scientific communities to enhance the monitoring and evaluation of key hypertension indicators.[9-11] Crucial to this effort is ongoing surveillance of hypertension detection, treatment, and control, along with accurate identification of vulnerable groups who are most susceptible to clinical care gaps. Identification of the major risk factors associated with uncontrolled BP is

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0.10; 95% CI 0.06-0.16) Framingham risk.

Conclusions: Large differences in levels of BP control exist across comorbidity profiles, and the greatest gaps are seen in individuals without recognized comorbidities, even those who have a moderate-to-high Framingham risk. Efforts to optimize BP control and narrow care gaps, especially in individuals without recognized comorbidities, are necessary to reduce the burden of cardiovascular disease and premature death in Canada.

de la PA était faible parmi de nombreuses personnes sans antécédent de crise cardiaque ou d'AVC, même chez celles qui présentaient un risque de Framingham modéré (RCa 0,25; IC à 95 % 0,17-0,37) ou élevé (RCa 0,10; IC à 95 % 0,06-0,16).

Conclusions : Il existe de grandes différences dans les niveaux de contrôle de la PA selon les profils de comorbidité, et les lacunes les plus importantes sont observées chez les personnes sans comorbidités reconnues, même chez celles qui présentent un risque de Framingham modéré à élevé. Des efforts pour optimiser le contrôle de la PA et réduire les écarts de soins, en particulier chez les personnes sans comorbidités reconnues, sont nécessaires pour réduire le fardeau des maladies cardiovasculaires et des décès prématurés au Canada.

necessary to inform effective health policy and targeted interventions.

Older age, a sedentary lifestyle, a low level of intake of fruits and vegetables, and a high level of sodium consumption are associated with a higher prevalence of hypertension, but none of these factors has been shown to independently predict worse BP control among Canadian adults.[12] Despite the importance of high BP, little work has been done in identifying the major predictors of uncontrolled BP.[13] To address this issue, we designed this study to assess whether medical conditions that commonly coexist with hypertension (including prior heart attack or stroke, dyslipidemia, chronic kidney disease, diabetes mellitus, obstructive sleep apnea, and overweight or obesity) may be associated with differences in BP treatment and control rates.

Methods

Data source

The data for this study are from the Canadian Health Measures Survey (CHMS), which is a serial cross-sectional survey designed to provide comprehensive, direct, and nationally representative health measures.[14,15] The CHMS sampling-area frame includes community-dwelling individuals, representing 96% of the Canadian population.[14] The first (2007-2009), second (2009-2011), third (2012-2013), fourth (2014-2015), fifth (2016-2017), and sixth (2018-2019) cycles of the CHMS were included in the present study, representing all available cycles.[16-20] Demographic, socioeconomic, health, and lifestyle information was collected through structured in-person interviews. History of stroke, diabetes, dyslipidemia, heart attack, kidney disease, and hypertension were self-reported. Respondents also were asked to provide details of their current medications, including the names, dosages, and the last time they were taken. Direct physical measurements, including BP, height, and weight, were subsequently recorded at mobile examination centres, using standardized techniques.[15,21]

Measures and definitions

Medications. To facilitate comparisons with previous studies, we ascertained treatment status, using Anatomical Therapeutic Chemical (ATC) Classification codes.[6,12,13,22-24] Survey respondents were considered to be using an antihypertensive drug if they reported taking at least one of the following medication types: beta-blockers, C07 (excluding C07AA07, C07AA12, and C07AG02); renin-angiotensin system inhibitors, C09; diuretics, C03 (excluding C03BA08); calcium-channel blockers, C08; and other antihypertensive drugs, C02 (excluding C02KX01).[6,12,22] Treatment for diabetes or dyslipidemia was based on a history of taking a glucose-lowering medication (A10) or a statin (C10AA, C10BA, or C10BX), respectively.

BP. Systolic BP (SBP) and diastolic BP (DBP) were measured at the mobile examination centre with BpTRU BPM-200 and BPM-300 oscillometric devices (BpTRU Medical Devices, Coquitlam, British Columbia, Canada).[25] After patients had 5 minutes of rest, 6 measurements were taken at 1-minute intervals, while participants were unattended, and the last 5 measurements then were used to determine the mean SBP and DBP levels.[25,26]

Hypertension. Respondents were defined as having hypertension if their mean SBP was $\geq$ 140 mm Hg or their mean DBP was $\geq$ 90 mm Hg, or if they reported using an antihypertensive medication in the past month.[6,12,23,27,28] Among respondents with hypertension, individuals were considered to be aware of their diagnosis if they reported having a history of high BP; further, respondents were classified as treated if they reported taking an antihypertensive medication within the past month, and their BP was classified as controlled if their mean SBP was under 140 mm Hg and their DBP was under 90 mm Hg (and in a sensitivity analysis we used $<$ 130/80 mm Hg to define control in those with diabetes).

Comorbidities. Selected medical comorbidities that commonly coexist with hypertension were assessed, to determine if these were associated with hypertension treatment and control rates, including diabetes mellitus, dyslipidemia, chronic kidney disease, obesity, prior heart attack or stroke, and obstructive sleep apnea. The presence of diabetes was determined by a self-reported history of diabetes, a glycated hemoglobin A1c level of $\geq$ 6.5%, and/or the use of a glucose-lowering medication. Dyslipidemia was defined by a self-reported history of having a high cholesterol level and/or the recent use of a statin. Kidney function was estimated using the Modification of Diet in Renal Disease equation, and the presence of chronic kidney disease was defined as an estimated glomerular filtration rate $<$ 60 mL/min per 1.73 m^2.[29] Individuals were considered to be overweight or obese if they had a body mass index (BMI) of $\geq$ 25.0 kg/m^2, based on their

Table 1. Characteristics of Canadian adults aged 20−79 years with hypertension

Characteristic	Cycle 1 (2007−2009)	Cycle 2 (2009−2011)	Cycle 3 (2012−2013)	Cycle 4 (2014−2015)	Cycle 5 (2016−2017)	Cycle 6 (2018−2019)	Overall
Mean age, y	60.7 (59.5−61.8)	59.4 (58.0−60.9)	60.2 (59.2−61.2)	60.7 (59.7−61.6)	61.4 (60.6−62.1)	61.0 (59.5−62.4)	60.5 (60.1−61.0)
Age bands, y							
20−39	3.6 (1.7−5.5)	6.5 (3.9−9.0)	4.1 (2.0−6.1)	5.4 (2.3−8.5)	3.0 (0.01−5.9)	7.0 (3.0−10.0)	5.0 (3.8−6.1)
40−59	37.3 (32.4−42.2)	39.8 (35.3−44.4)	41.5 (35.9−47.1)	36.6 (31.8−41.5)	37.8 (30.7−45.0)	32.5 (28.1−36.8)	37.6 (35.3−39.8)
60−69	35.3 (30.9−39.8)	32.2 (28.0−36.4)	31.2 (28.2−34.2)	32.7 (27.0−38.5)	37.1 (32.7−41.4)	32.4 (26.9−38.0)	33.4 (31.4−35.3)
70−79	23.8 (19.3−28.3)	21.6 (17.7−25.4)	23.2 (18.1−28.3)	25.3 (23.2−27.4)	22.2 (18.9−25.4)	28.1 (23.0−33.6)	24.1 (22.3−25.8)
Male	51.5 (49.3−53.7)	58.9 (53.7−64.1)	51.1 (46.1−56.1)	53.2 (48.0−58.4)	50.2 (45.3−55.1)	59.3 (54.8−63.8)	54.2 (52.0−56.3)
White ethnicity	87.3 (76.8−97.8)	84.2 (74.6−93.7)	83.5 (73.5−93.6)	87.7 (81.2−94.3)	81.6 (70.5−92.7)	74.4 (62.3−86.6)	83.0 (78.6−87.4)
Current smoker	15.0 (12.0−18.0)	15.6 (12.5−18.7)	24.0 (18.5−29.4)	11.9 (8.9−14.9)	13.8 (9.4−18.1)	14.8 (10.6−18.9)	15.9 (14.3−17.4)
Mean systolic blood pressure, mm Hg	127.9 (126.0−129.8)	126.6 (124.1−129.0)	126.0 (123.9−128.1)	127.7 (126.1−129.4)	130.8 (127.7−133.9)	126.1 (123.7−128.4)	127.5 (126.6−128.4)
Mean diastolic blood pressure, mm Hg	76.3 (74.9−77.7)	77.1 (75.1−79.0)	75.8 (74.7−76.9)	77.0 (75.8−78.3)	78.7 (77.3−80.1)	77.2 (75.9−78.6)	77.0 (76.4−77.6)
Mean systolic blood pressure (adjusted), mm Hg*	130.3 (128.5−132.1)	129.1 (126.9−131.4)	128.6 (126.6−130.5)	130.2 (128.6−131.7)	133.1 (130.2−136.0)	128.6 (126.5−130.8)	130.0 (129.1−130.8)
Mean diastolic blood pressure (adjusted), mm Hg*	78.9 (77.8−80.1)	79.6 (78.0−81.2)	78.5 (77.6−79.5)	79.5 (78.5−80.6)	80.9 (79.7−82.1)	79.7 (78.6−80.8)	79.5 (79.0−80.0)
Overweight or obese	77.9 (72.7−83.1)	82.6 (78.6−86.7)	79.1 (72.7−85.6)	82.0 (77.0−87.0)	79.7 (73.5−86.0)	80.2 (73.8−86.5)	80.4 (77.8−82.9)
Chronic kidney disease	13.0 (10.1−16.0)	14.8 (11.2−18.4)	12.4 (7.4−17.4)	13.4 (10.8−16.1)	11.2 (9.1−13.2)	18.6 (13.1−24.1)	14.0 (12.4−15.5)
Diabetes	23.0 (17.5−28.4)	26.0 (21.9−30.1)	22.2 (17.3−27.0)	22.2 (18.4−26.0)	27.4 (22.9−31.9)	22.2 (16.4−28.1)	23.9 (22.0−25.8)
Dyslipidemia	52.0 (48.9−55.1)	53.7 (48.8−58.7)	51.9 (43.5−60.4)	50.1 (46.0−54.3)	53.3 (46.3−60.2)	52.7 (46.3−59.0)	52.3 (50.1−54.6)
Heart attack	11.1 (9.0−13.2)	8.3 (5.2−11.5)	9.4 (5.6−13.2)	9.1 (5.9−12.3)	7.1 (4.4−9.7)	8.7 (4.6−12.8)	8.9 (7.7−10.1)
Stroke	2.6 (1.5−3.6)	3.8 (1.9−5.6)	2.1 (0.7−3.4)	2.3 (1.4−3.2)	1.9 (1.0−2.9)	2.1 (0.7−3.6)	2.5 (1.9−3.0)
Obstructive sleep apnea†	N/A	N/A	N/A	N/A	11.2 (9.6−12.9)	12.3 (8.6−16.0)	11.7 (9.7−13.8)
Family history of high blood pressure†	59.0 (54.3−63.7)	61.7 (58.4−65.0)	57.8 (51.9−63.7)	65.7 (61.0−70.3)	N/A	N/A	61.2 (58.8−63.5)
Family history of early cardiovascular disease†	47.4 (42.5−52.2)	42.8 (37.5−48.1)	47.6 (40.7−54.4)	45.9 (39.2−52.7)	N/A	N/A	45.7 (42.5−48.9)
Framingham risk, %‡							
< 10	27.3 (23.9−30.7)	29.3 (24.1−34.4)	30.8 (25.8−35.8)	30.9 (24.9−37.0)	26.7 (23.1−30.3)	16.2 (2.6−29.7)	27.2 (25.3−29.2)
10−19	35.3 (29.1−41.6)	37.5 (31.6−43.3)	37.9 (30.2−45.7)	34.0 (30.0−37.9)	38.1 (33.0−43.2)	35.7 (22.4−49.0)	36.5 (34.0−38.9)
≥ 20	37.4 (32.2−42.5)	33.3 (29.9−36.6)	31.3 (25.5−37.0)	35.1 (30.7−39.4)	35.2 (31.6−38.8)	48.1 (36.1−60.2)	36.3 (34.6−38.0)

Values are percentage (95% confidence interval [CI]), or where indicated, mean (95% CI). Percentages, means, and their CIs are based on weighted and bootstrapped estimates.

*Adjusted systolic blood pressure = 11.4 + (0.93 × BpTRU-measured systolic blood pressure), and adjusted diastolic blood pressure = 15.6 + (0.83 × BpTRU-measured diastolic blood pressure; BpTRU Medical Devices, Coquitlam, British Columbia, Canada).[33]

†History of obstructive sleep apnea available for only cycles 5 and 6. Family history of high blood pressure or early cardiovascular disease available for only cycles 1-4.

‡Framingham risk not calculated for people with known history of heart attack and/or stroke.

Table 2. Canadian rates for prevalence, awareness, treatment, and control of hypertension

Characteristic	Cycle 1 (2007−2009)	Cycle 2 (2009−2011)	Cycle 3 (2012−2013)	Cycle 4 (2014−2015)	Cycle 5 (2016−2017)	Cycle 6 (2018−2019)	Overall
Total population represented, n	3,730,395	4,564,105	4,118,069	4,213,536	4,311,209	4,498,685	25,436,000
Number of people with hypertension, n	794,071	1,078,740	980,010	998,928	985,955	1,003,749	5,841,453
Hypertension							
Prevalence, overall	21.2 (19.4−23.1)	23.6 (21.1−26.1)	23.8 (21.3−26.3)	23.7 (20.8−26.6)	22.9 (20.7−25.0)	22.3 (18.3−26.3)	23.0 (21.7−24.2)
Female participants	20.4 (18.8−22.0)	19.3 (16.7−21.8)	23.1 (19.1−27.0)	21.9 (17.9−26.0)	22.6 (19.0−26.2)	18.0 (14.6−21.4)	20.8 (19.4−22.3)
Male participants	22.2 (19.7−24.6)	28.00 (23.5−32.5)	24.5 (21.7−27.3)	25.4 (22.0−28.9)	23.2 (20.5−26.0)	26.7 (21.1−32)	25.1 (23.4−26.9)
Awareness of having condition, overall	85.6 (82.7−88.6)	84.7 (80.5−89.0)	87.5 (82.9−92.0)	82.4 (78.4−86.4)	77.4 (70.8−84.0)	79.3 (73.7−85.0)	82.8 (80.8−84.7)
Female participants	87.9 (84.0−91.8)	84.5 (79.3−89.8)	83.1 (75.7−90.5)	85.1 (80.6−89.5)	72.2 (64.1−80.2)	80.7 (70.7−90.7)	82.0 (79.2−84.8)
Male participants	83.6 (79.5−87.6)	84.9 (78.5−91.2)	91.6 (87.7−95.6)	80.1 (73.3−87.0)	82.6 (75.1−90.1)	78.4 (70.4−86.3)	83.4 (80.7−86.2)
Treatment, overall	82.3 (79.1−85.5)	80.1 (74.2−86.0)	81.8 (75.8−87.8)	79.0 (72.7−85.2)	72.0 (64.4−79.7)	77.5 (71.7−83.2)	78.7 (76.3−81.2)
Female participants	84.7 (80.0−89.4)	83.6 (78.5−88.6)	81.0 (74.1−88.0)	80.1 (73.8−86.4)	65.2 (57.6−72.8)	78.6 (69.0−88.2)	78.5 (75.6−81.5)
Male participants	80.0 (76.1−83.9)	77.6 (68.4−86.9)	82.5 (73.7−91.3)	77.9 (68.7−87.2)	78.8 (70.3−87.2)	76.7 (69.0−84.3)	78.8 (75.4−82.3)
Controlled, overall	69.0 (64.9−73.0)	66.8 (59.5−74.0)	69.9 (64.2−75.6)	63.6 (58.1−69.2)	58.3 (49.5−67.2)	63.9 (58.7−69.1)	65.2 (62.6−67.8)
Female participants	67.9 (62.3−73.5)	69.0 (62.4−75.7)	68.9 (62.7−75.0)	62.4 (55.5−69.2)	49.2 (39.7−58.7)	62.9 (54.1−71.6)	63.1 (59.9−66.3)
Male participants	70.0 (66.1−73.9)	65.2 (54.6−75.8)	70.9 (58.7−83.1)	64.8 (57.7−71.8)	67.4 (58.9−75.9)	64.6 (58.6−70.6)	67.0 (63.4−70.5)

Values are % (95% confidence interval), unless otherwise indicated.

measured height and weight. The presence of a prior history of heart attack or stroke, obstructive sleep apnea, and smoking, as well as any family history of high BP or early cardiovascular disease (ie, heart disease or stroke before age 60 years) were ascertained by self-report.

Statistical analysis

We obtained stable population estimates by pooling data from all available cycles of the CHMS, as recommended by Statistics Canada.[30] Descriptive statistics were used to examine the characteristics of the population. Nationally representative estimates were calculated by applying respondent-specific survey weights, and corresponding variances (95% confidence intervals [CIs]) were estimated using bootstrapping.[16-18,30,31] The prevalence of hypertension and the frequencies of patient awareness of it, and its treatment and control, were calculated. Stratified analyses were performed to explore for potential differences between the female and male populations, according to age, and across the comorbidities we examined. Logistic regression modelling was used to estimate the adjusted odds ratio (aOR) for patient awareness of hypertension, and for its treatment and control, according to the covariates of interest, adjusting for age and sex. As in previous studies,[12,27,32] a sensitivity analysis was performed to account for the possibility that BP measurements from the BpTRU device are lower than conventional manual BP measurements, using the following formulas[33]: adjusted SBP = 11.4 + (0.93 × BpTRU-measured SBP), and adjusted DBP = 15.6 + (0.83 × BpTRU-measured DBP). Accordingly, the adjusted SBP and DBP then were used to re-estimate the prevalence of hypertension and control. Furthermore, a second sensitivity analysis was performed to account for the presence of diabetes, such that hypertension was considered to be present when the SBP was $\geq$ 130 mm Hg or the DBP was $\geq$ 80 mm Hg for those with diabetes, and BP measurements < 130/80 mm Hg were considered controlled. All statistical analyses were performed using STATA 16 (StataCorp, College Station, TX).

Results

After applying respondent-specific survey weights, 5,841,453 Canadian adults were estimated to have hypertension during the entire study period (2007-2019). Their mean SBP and DBP were 127.5 mm Hg and 77.0 mm Hg, respectively. Their baseline characteristics generally were similar across all years (Table 1). Their average age was 60.5 years, and male individuals had a slight preponderance (54.2%). Individuals with hypertension were commonly overweight or obese (80.4%), had dyslipidemia (52.3%), and had diabetes (23.9%). Chronic kidney disease was relatively prevalent, and rose in frequency over time (ie, from 13.0% to 18.6% from 2007 to 2019). Approximately 1 in 10 people reported having obstructive sleep apnea or having had a previous heart attack. The majority of individuals with hypertension were at moderate to high cardiovascular risk (ie, 72.8% of people had an estimated 10-year risk of incident cardiovascular disease of $\geq$ 10%, based on their Framingham risk score).

The overall prevalence of hypertension in the adult population was 23.0% across all years, with a similar frequency from cycle to cycle (Table 2). Of those with hypertension,

Table 3. Rates of patient awareness of having hypertension, its treatment, and its control, stratified by major comorbidities, family history, and cardiovascular risk

Category	Major comorbidities							Framingham risk, %[‡]		
	None	Overweight or obese	Obstructive sleep apnea[†]	Chronic kidney disease	Diabetes	Dyslipid-emia	Prior heart attack or stroke	< 10-	10–19	≥ 20
Overall number, n*	544,390	4,826,414	243,969	801,725	1,603,596	3,170,001	635,261	1,423,142	1,973,295	1,960,591
Hypertension prevalence	9.0 (7.4–10.6)	80.3 (77.8–82.9)	11.8 (9.8–13.8)	13.6 (12.1–15.1)	26.5 (24.5–28.6)	52.4 (50.1–54.7)	10.5 (9.2–11.8)	–	–	–
Hypertension Patient unaware	38.4 (30.6–46.2)	18.0 (15.7–20.3)	10.4 (5.0–15.9)	6.4 (4.1–8.7)	14.6 (11.3–17.8)	10.0 (7.6–12.4)	1.7 (0.4–3.0)	26.6 (24.3–29.0)	36.8 (34.1–39.6)	36.6 (34.8–38.4)
Patient aware, but untreated	9.3 (3.8–14.8)	3.6 (2.4–4.7)	1.0 (0–2.4)	1.2 (0.1–2.4)	1.6 (0.6–2.7)	2.3 (1.2–3.3)	0.9 (0–2.0)	5.3 (3.8–7.2)		2.7 (1.5–4.6)
Treated, uncontrolled	14.1 (7.4–20.7)	12.8 (11.1–14.5)	16.0 (9.3–22.8)	18.8 (14.9–22.7)	11.8 (9.4–14.2)	12.9 (10.8–15.1)	13.3 (10.3–16.4)	1.5 (0.7–3.1)	10.5 (8.3–13.4)	23.8 (20.3–27.7)
Treated, controlled	38.2 (30.9–45.6)	64.9 (62.2–67.6)	72.5 (64.9–80.1)	73.3 (68.6–77.9)	69.4 (65.1–73.7)	73.7 (70.2–77.1)	84.1 (80.5–87.7)	69.9 (64.0–75.3)	60.1 (56.1–63.9)	53.6 (49.5–57.6)

Values are % (95% confidence interval), unless otherwise indicated. In accordance with Statistics Canada's policy, estimates based on small sample sizes or high sampling variation were handled by combining multiple cells, to satisfy the minimum requirements for vetting, release, and publication.

* Based on an overall number of 6,050,065 Canadian adults, accounting for the presence of diabetes, with a mean systolic blood pressure ≥ 130 mm Hg, or a mean diastolic blood pressure ≥ 80 mm Hg, considered to be an elevated blood pressure, and with blood pressure measurements < 130/80 mm Hg controlled.

† History of obstructive sleep apnea available for only cycles 5 and 6.

‡ Framingham risk was not calculated for people with a known history of heart attack and/or stroke.

82.8% of respondents were aware of their condition. The percentage of people with hypertension who were aware of their condition was 85.0% in cycles 1-4 (2007-2015), 77.4% in cycle 5 (2016-2017), and 79.3% in the most recent cycle (2018-2019). Similarly, although hypertension treatment and control appeared to decline by around 7% each in cycle 5 (2016-2017), this decline no longer was apparent in the most recent cycle (ie, 77.5% and 63.9%, respectively, in cycle 6 [2018-2019]).

The main findings remained consistent after adjustment was made for differences in BP readings obtained with the BpTRU oscillometric device (compared to manual BP measurement). The adjusted mean SBP and DBP readings were approximately 2.5 mm Hg higher than the recorded measurements (Table 1). The corresponding rates of hypertension prevalence (23.1%; 95% CI, 21.9% to 24.3%), patient awareness (82.3%; 95% CI, 80.2% to 84.1%), treatment (78.2%; 95% CI, 75.7%-80.5%), and control (64.2%; 95% CI, 61.5%-66.7%) were nearly identical using the adjusted BPs, compared to those of the main analysis. After accounting for the presence of diabetes, 6,050,065 Canadian adults were identified as having hypertension. Similarly, only minimal changes occurred in hypertension prevalence (23.8%; 95% CI, 22.5%-25.0%), patient awareness (80.6%; 95% CI, 78.7%-82.6%), treatment (76.0%; 95% CI, 73.6%-78.4%), and control (58.4%; 95% CI, 55.8%-61.1%) after accounting for a lower BP threshold and treatment target of 130/80 mm Hg for people with diabetes.

The frequencies of patient awareness of hypertension, and its treatment, varied across comorbidities (Table 3; Fig. 1). Hypertension was present in as many as 80.3% (95% CI, 77.8%-82.9%) of overweight or obese adults, 52.4% (95% CI, 50.1%-54.7%) of those with dyslipidemia, and 26.5% (95% CI, 24.5%-28.6%) of those with diabetes, but its prevalence was 9.0% (95% CI, 7.4%-10.6%) in individuals without any of the major comorbidities examined. Nearly all respondents with hypertension who had a prior history of heart attack or stroke (98.3%) were aware of their history of high blood pressure, and among these, very few (0.9%) were untreated. People with chronic kidney disease, diabetes, dyslipidemia, and obstructive sleep apnea consistently had high rates of awareness of their hypertension (> 85%), with very few being untreated (at most, 2.3%). Those who were overweight or obese had slightly lower rates of awareness of their hypertension (82.0%), but only a few were aware but yet untreated (3.6%). In contrast, otherwise healthy individuals with a high BP (ie, without any of the major comorbidities of interest) frequently were unaware that they had hypertension (38.4%); nearly 1 in 10 were untreated (9.3%), and < 4 in 10 had controlled BP (38.2%). The prevalence of treatment and control of hypertension was highest among those with a history of heart attack or stroke (84.1%), lower in patients with chronic kidney disease or diabetes (73.3% and 69.4%, respectively), and lowest in the absence of any major comorbidity (38.2%). In contrast, when patients were examined according to Framingham risk profiles (after excluding people with prior heart attack or stroke), more than two-thirds (69.9%) of individuals in the lowest-risk group (ie, those with a 10-year risk of incident cardiovascular disease < 10%) had their hypertension treated and controlled, compared to only around half of hypertensive people (53.6%) in the

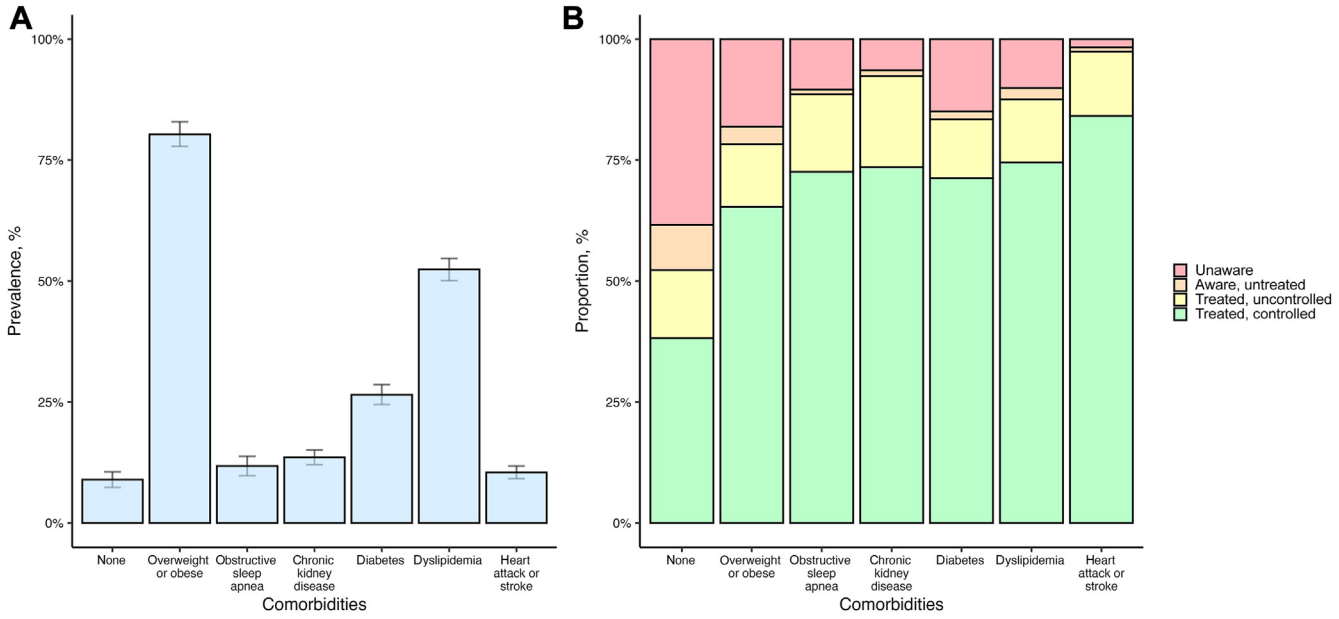

Figure 1. (**A**) Hypertension prevalence, stratified by major comorbidities. (**B**) Indicators of patient awareness of their hypertension, and for its treatment and control, stratified by major comorbidities.

highest-risk group (ie, those with a 10-year risk of incident cardiovascular disease $\geq$ 20%).

In the regression analysis, after adjusting for age and sex, a prior history of heart attack or stroke was associated with a 3-fold higher adjusted odds of having controlled BP, compared to hypertensive people who had not previously had one of these events (aOR 3.15; 95% CI, 2.31-4.31; Fig. 2). The adjusted odds of having hypertension treated and controlled was also higher among individuals with dyslipidemia (aOR 2.51; 95% CI, 1.96-3.21), obstructive sleep apnea (aOR 1.95; 95% CI, 1.19-3.21), overweight or obesity (aOR 1.51; 95% CI, 1.18-1.94), chronic kidney disease (aOR 1.49; 95% CI, 1.13-1.95), or diabetes (aOR 1.44; 95% CI, 1.12-1.86), compared to the odds in hypertensive adults without these conditions. Individuals with high BP but no reported history of any major comorbidity were nearly 3 times more likely to be left untreated for their hypertension, even when they were aware of it (aOR 2.65; 95% CI, 1.14-6.17), and were less than half as likely to have their BP treated and under control (aOR 0.34; 95% CI, 0.0.25-0.48).

Discussion

In this study, we found that nearly a quarter of community-dwelling Canadian adults have hypertension. Among them, nearly 80% are treated with BP-lowering medications, and just under two-thirds have controlled BP. The strongest factor associated with hypertension treatment and BP control in this study was a prior history of heart attack or stroke. In contrast, the prevalence of treatment and control was low among people with none of the comorbidities we examined (diabetes, dyslipidemia, chronic kidney disease, overweight or obesity, and obstructive sleep apnea), even in those who were at moderate-to-high cardiovascular risk. Our findings are encouraging in that many people with hypertension and comorbidities have their BP treated and controlled, but a group of Canadians with uncontrolled BP remains, who (although not yet having suffered a heart attack or stroke) are still vulnerable to experiencing a cardiovascular event and would therefore benefit from BP reduction.

Our findings are consistent with and extend those of previous reports. Few studies have explored what factors are associated with hypertension treatment and BP control in Canada. In results similar to those of the present study, McAlister and colleagues reported a 2- to 3-fold higher odds of BP control among respondents who had a prior history of heart attack or stroke, compared to that among people who had never experienced either one of these events, in Canadian data from the first cycle (2007-2009) of the CHMS and the Canadian Heart Health Surveys (1986-1992).[32] In a subsequent analysis of later cycles of the CHMS, Gee and colleagues found that older women had a more than 2-fold higher odds of having uncontrolled BP, despite receiving treatment, compared to men of similar age.[34] After adjustment for age and sex, no other sociodemographic factors or health behaviours were found to be associated with BP control. More recently, to elucidate the differences between older women and men, Bushnik and colleagues re-examined the CHMS, using 4 cycles of the survey (2007-2015), and they looked for sex-specific risk factors associated with BP control.[22] They found that the presence of diabetes commonly was associated with worse BP control in older adults, aged $>$ 60 years (but only when applying the diabetes-specific BP target of $<$ 130/80 mm Hg). In older men, the presence of heart disease or stroke was associated with improved BP control, compared to that among those without a history of cardiovascular disease, but this association was not present among older women.

Unique to the present study, we found large differences across multiple key indicators of BP care, according to major comorbidities that frequently coexist with hypertension in the

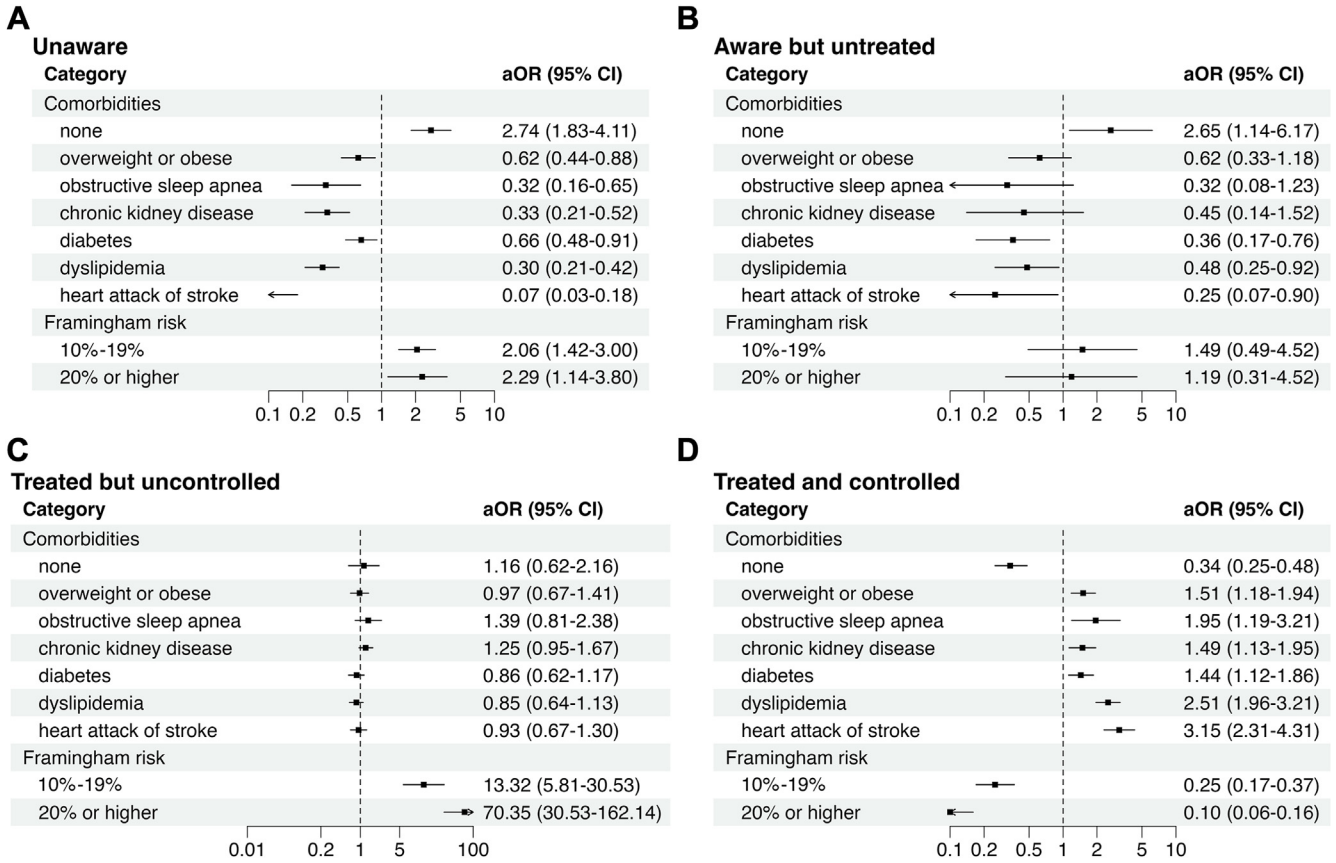

Figure 2. (**A**) Ajusted odds ratio (aOR), adjusted for age and sex, for key indicators of hypertension care according to major comorbidities and cardiovascular risk: (**A**) patient aware of their hypertension; (**B**) patient aware of but untreated for hypertension; (**C**) patient treated for but has uncontrolled hypertension; (**D**) patient treated for and has controlled hypertension. Under the heading of comorbidities, the reference group for "none" was the presence of any of the below comorbidities; the reference group for the remaining rows was the absence of the stated condition. For Framingham risk, the reference group was an estimated 10-year risk $< 10\%$. Overall estimates based on 6,050,065 Canadian adults, accounting for the presence of diabetes, with a mean systolic blood pressure $\geq$ 130 mm Hg, or a mean diastolic blood pressure $\geq$ 80 mm Hg considered an elevated BP, and with BP measurements $<$ 130/80 mm Hg controlled. The Framingham risk was not calculated for people with a known history of heart attack and/or stroke. CI, confidence interval.

population. As expected, the level of patient awareness of hypertension, and the prevalence of its treatment and control were by far the highest among individuals who had a previous cardiovascular event (ie, prior history of heart attack or stroke), possibly because they were targeted intensively for BP control by their providers and potentially were more likely to adhere to therapy.[24,35] Moreover, many antihypertensive agents are indicated clinically to reduce vascular risk, independent of BP control (eg, angiotensin-converting enzyme inhibitors and beta-blockers in many patients with ischemic heart disease),[36] thereby also explaining why some high-risk groups were more likely to be treated. Correspondingly, the odds of having one's BP treated and controlled generally were higher in patients with associated comorbidities, including dyslipidemia, obstructive sleep apnea, overweight or obesity, chronic kidney disease, and diabetes, potentially because many of these patients have frequent healthcare encounters and thus increased opportunity to have their hypertension identified and treated. This finding is encouraging because BP-lowering will lead to the greatest absolute benefit in those with the highest baseline risk.[5,37]

Disappointing, however, were the findings that among respondents with none of the major comorbidities of interest, nearly half were overlooked for treatment, and among those who were treated, most still had uncontrolled BP, indicating a large care gap that affects hundreds of thousands of Canadians. Potential reasons for this gap include infrequent interactions with healthcare providers, an unfavourable risk-to-benefit ratio for antihypertensive treatment (either real or perceived), and clinical inertia. Public health campaigns and community screening programs could be effective interventions to target individuals who may otherwise be missed in traditional healthcare settings.[38] Future research is needed to determine the best ways to target such individuals in Canada.

Of concern, as well, was the fact that (after excluding respondents with a known history of heart attack or stroke) the proportion of people, without the comorbidities we examined, who had treated, yet uncontrolled BP, paradoxically rose as the Framingham risk increased. The underlying reasons driving these differences could not be identified here, but possibly, people with a higher Framingham risk tended to

have a lower awareness level, and decreased prevalence of both treatment and control of other pertinent cardiovascular risk factors (eg, diabetes, dyslipidemia, and smoking). Reassuringly, in the most recent cycle of the CHMS, the previously reported disparity in the prevalence of hypertension treatment and control for male vs female patients was narrowed.[6] Ongoing surveillance is needed to confirm that this latter trend is sustained.

This study was subject to certain limitations. First, the CHMS was a voluntary survey, with a response rate of approximately 50%. Although this rate was taken into account in the survey weights, to ensure that respondents were representative of the target population, according to their sociodemographic characteristics, we cannot exclude the possibility of bias having arisen from clinical differences between responders and nonresponders. Second, data on the presence of many of the comorbidities of interest and the use of medications were gathered by questionnaire and were not verified with medical records, which may have led to some misclassification. Finally, treatment status was ascertained using Anatomical Therapeutic Chemical Classification codes alone,[6,12,13,22-24] and therefore, the primary indication for the prescription of an antihypertensive drug was not known (ie, whether it was given for high BP or another condition). Given this limitation, the estimated treatment rates may have been subject to some degree of misclassification, although the impact of this likely would have been very small.[13]

Improvements in hypertension treatment and BP control need to remain national priorities.[9-11] Despite the considerable effort made to improve hypertension management in the past several decades, significant care gaps persist.[9-11] Over a million Canadians with hypertension (many of whom are at moderate-to-high cardiovascular risk) remain unaware of it, or have untreated or uncontrolled BP. Continued efforts to both optimize BP control and narrow existing care gaps are necessary to reduce the burden of cardiovascular disease, preventable disability, and premature death in Canada.

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A.A.L. and J.V.A.W. had full access to all of the CHMS data in this study and take responsibility for the integrity of the CHMS data and the accuracy of the data analysis.

Ethics Statement

This study used publicly-available data from Statistics Canada which are exempt from research ethics board review as per the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS2), article 2.2.

Patient Consent

The authors confirm that patient consent is not applicable to this article.

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Disclosures

The authors have no competing interests to disclose.

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