Estimate of the benefits of a population-based reduction in dietary sodium additives on hypertension and its related health care costs in Canada

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BACKGROUND: Hypertension is the leading risk factor for mortality worldwide. One-quarter of the adult Canadian population has hypertension, and more than 90% of the population is estimated to develop hypertension if they live an average lifespan. Reductions in dietary sodium additives significantly lower systolic and diastolic blood pressure, and population reductions in dietary sodium are recommended by major scientific and public health organizations.

OBJECTIVES: To estimate the reduction in hypertension prevalence and specific hypertension management cost savings associated with a population-wide reduction in dietary sodium additives.

METHODS: Based on data from clinical trials, reducing dietary sodium additives by 1840 mg/day would result in a decrease of 5.06 mmHg (systolic) and 2.7 mmHg (diastolic) blood pressures. Using Canadian Heart Health Survey data, the resulting reduction in hypertension was estimated. Costs of laboratory testing and physician visits were based on 2001 to 2003 Ontario Health Insurance Plan data, and the number of physician visits and costs of medications for patients with hypertension were taken from 2003 IMS Canada. To estimate the reduction in total physician visits and laboratory costs, current estimates of aware hypertensive patients in Canada were used from the Canadian Community Health Survey.

RESULTS: Reducing dietary sodium additives may decrease hypertension prevalence by 30%, resulting in one million fewer hypertensive patients in Canada, and almost double the treatment and control rate. Direct cost savings related to fewer physician visits, laboratory tests and lower medication use are estimated to be approximately $430 million per year. Physician visits and laboratory costs would decrease by 6.5%, and 23% fewer treated hypertensive patients would require medications for control of blood pressure.

CONCLUSIONS: Based on these estimates, lowering dietary sodium additives would lead to a large reduction in hypertension prevalence and result in health care cost savings in Canada.

Key Words: *Blood pressure; Cost-benefit analysis; Diet; Hypertension; Population health; Prevention; Sodium*

L'évaluation des bienfaits de la réduction des additifs alimentaires au sodium en population générale sur l'hypertension et sur les coûts de santé connexes au Canada

HISTORIQUE : L'hypertension est le principal facteur de risque de mortalité dans le monde. Le quart de la population canadienne adulte fait de l'hypertension, et on estime que plus de 90 % de la population se met à en faire si elle vit une longévité moyenne. Les réductions aux additifs alimentaires au sodium réduisent considérablement la tension artérielle systolique et diastolique, et les principaux organismes scientifiques et de santé publique recommandent des réductions de sodium alimentaire dans la population.

OBJECTIFS : Évaluer la réduction de la prévalence d'hypertension et les épargnes sur la prise en charge de l'hypertension associées à une réduction des additifs alimentaires au sodium en population générale.

MÉTHODOLOGIE : D'après les données d'essais cliniques, une diminution des additifs alimentaires au sodium de 1 840 mg/jour favoriserait une réduction des tensions artérielles systolique de 5,06 mmHg et diastolique de 2,7 mmHg. Au moyen des données de l'Enquête canadienne sur la santé cardiovasculaire, on a évalué la réduction sur l'hypertension qui en résulterait. On a établi les coûts des tests de laboratoire et des consultations de médecins d'après les données du régime d'assurance-maladie de l'Ontario entre 2001 et 2003, et le nombre de consultations de médecins et le coût des médicaments pour les patients hypertensifs d'après IMS Canada en 2003. Pour évaluer la réduction du total de consultations de médecins et des coûts de laboratoire, les évaluations courantes du nombre d'hypertensifs connus au Canada provenaient de l'Enquête sur la santé dans les collectivités canadiennes.

RÉSULTATS : En limitant les additifs alimentaires en sodium, on peut réduire la prévalence d'hypertension de 30 %, ce qui diminuerait de un million le nombre d'hypertensifs au Canada et qui doublerait pratiquement le taux de traitement et de contrôle. Les économies directes reliées au moins grand nombre de consultations de médecins, de tests de laboratoire et d'usage de médicaments sont évaluées à environ 430 millions de dollars par année. Les consultations de médecins et les coûts de laboratoire chuteraient de 6,5 %, et 23 % de moins d'hypertensifs traités auraient besoin de médicaments pour contrôler l'hypertension.

CONCLUSIONS : D'après ces évaluations, la diminution des additifs alimentaires en sodium entraînerait une forte réduction de la prévalence d'hypertension et assurerait des économies en santé au Canada.

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The World Health Organization (WHO) estimates hypertension to be the leading risk factor for death in the world (1). In part, this is because hypertension is common, occurring in nearly one-quarter of the world's adult population, and because the management of hypertension is suboptimal (2,3). A significant proportion of hypertensive patients (42%) are unaware that their blood pressure (BP) is elevated, and many of those who are aware are either untreated or undertreated (3,4). As such, only a minority of hypertensive patients are treated to recommended targets (3,4). The WHO and many national scientific and public health organizations have called for enhanced diagnosis, treatment and control of hypertension as a cost-effective way to reduce morbidity and mortality (5). Improving the management of hypertension through better diagnosis, treatment and control, however, will require extensive resources and result in significant costs, which may be unaffordable in many countries (6). These costs could be avoided if the prevalence of hypertension was reduced.

Prevention of the development of hypertension by reducing the mean BP in the population is another mechanism by which the adverse health consequences of hypertension may be reduced (5,7). Because the prevalence of hypertension is predicted to substantially increase due to an aging and an increasingly sedentary population, a focus on prevention is now more urgent than ever (8,9). More than 90% of those 55 to 65 years of age with normal BP are estimated to develop hypertension during their lifespans (10). National guidelines have emphasized the importance of counselling for patients on lifestyle modifications for both the prevention and management of hypertension (11-14). However, despite the potential of lifestyle modifications resulting in large BP reductions, even within rigorous clinical trials with extensive resources for individualized counselling, only modest improvements in BP have been observed (15).

An alternative approach to individual counselling recommended by international public health organizations involves the creation of environments that support healthy lifestyles (16,17). Although many environmental changes would require long-term structural changes within our society, changes to the processing of food may represent an opportunity to more rapidly improve public health. In the past five to 10 years, major international and national scientific organizations have recommended reductions in dietary sodium by reducing sodium additives to food. In 2003, the Scientific Advisory Committee on Nutrition (United Kingdom) indicated that "there is compelling evidence that this (a population reduction in dietary sodium to 2400 mg/day) is an effective and appropriate means to reduce the public health burden of cardiovascular disease to society" (18). The WHO used reduction in dietary sodium additives as one of very few examples of 'bold policies' required to improve global health (5). The American Medical Association, the American Public Health Association and the American Heart Association have developed policies calling for a 50% reduction in sodium additives to foods by 2012 (19-21).

In 2004, the National Academy of Sciences (United States) was commissioned by the American and Canadian governments to update nutritional recommendations for sodium and other nutrients based on a comprehensive scientific review. The report (22) recommended that adult dietary sodium intake should be below 2300 mg/day, with 1200 mg/day to 1500 mg/day being considered an adequate intake for optimal health. More recently, the Canadian Hypertension Education Program has also recommended dietary sodium intake of less than 100 mmol (2300 mg) per day for the prevention of hypertension (www.hypertension.ca). However, a recent survey found that adult Canadians consume on average 3100 mg/day of sodium, excluding the salt added in cooking and at the table (22). Approximately 10% to 20% of dietary sodium is added in cooking and at the table; therefore, adult Canadians are likely consuming an average of approximately 3500 mg/day (23). Reducing dietary sodium by 1840 mg/day is estimated to reduce BP by 5.06/2.70 mmHg in adult hypertensive patients (24) and would result in sodium intakes close to that recommended as adequate for Canadians by the National Academy of Sciences (ie, 3500 mg/day – 1840 mg/day = 1660 mg/day). In the present study, we modelled the impact of a population-wide reduction in dietary sodium intake by 1840 mg/day in Canada on the prevalence of hypertension, improvements in the awareness, treatment and control rates for hypertension, as well as reductions in costs for physician visits, antihypertensive medications and laboratory services.

METHODS

The Canadian Heart Health Surveys

The Canadian Heart Health Surveys (CHHS) were used to determine the baseline prevalence of hypertension in Canada for the present study (3,4,25). The CHHS took place between 1986 and 1992, and represent the last available actual measurement data on hypertension prevalence, awareness, treatment and control in Canada. For the CHHS, 29,855 individuals were randomly selected as participants, 23,129 of whom participated. Details of the study methodology have been published elsewhere (25,26). BPs were measured by a trained nurse at the beginning and end of each visit using a standardized protocol. Hypertension was defined in the present study as a mean systolic BP (SBP) of 140 mmHg or greater, or a mean diastolic BP (DBP) of 90 mmHg or greater, or a patient having been prescribed antihypertensive medication. Nonpharmacological treatment was not used in the present study to define treatment status. Measurements were weighted to account for the sampling design and therefore represent population estimates. Individuals who reported having been told by a physician or nurse that they had high BP, but were not treated (with medications or with nonpharmacological advice), and who had a normal mean BP were not included in the hypertension group in the CHHS.

For the purposes of defining the prevalence of hypertension in the present study, treated individuals who answered 'yes' to the following questions were removed: "What were you told to do for your high blood pressure? Go on a salt-free diet?" and, "What program are you now following for your high blood pressure? Go on a salt-free diet?" It was assumed that these individuals were already on a sodium-restricted diet, which resulted in the removal of 14.9% of aware hypertensive patients.

Estimated BP reduction associated with sodium restriction

The effect of reducing dietary sodium intake by 1840 mg/day (equivalent to 78 mmol or 4600 mg of sodium chloride) per 24 h in individuals with elevated BP was obtained from a recently updated Cochrane review meta-analysis (24). The meta-analysis was based on 20 trials (n=802) and the mean reduction in BP was –5.06 mmHg (95% CI –5.81 mmHg to –4.31 mmHg) in SBP and

–2.70 mmHg (95% CI –3.16 mmHg to –2.24 mmHg) in DBP in hypertensive adults. As such, it was assumed that if a population-based intervention could reduce dietary sodium intake by 1840 mg/day, the mean SBP and DBP would be reduced by 5.06 mmHg and 2.7 mmHg, respectively, for each hypertensive adult Canadian. This was used to determine new estimates of the prevalence, awareness, treatment and control of hypertension in the CHHS.

Estimates of the reduction in BP that would be expected from the use of antihypertensive drugs were obtained from the meta-analysis by Law et al (27). To estimate the reduction in antihypertensive therapy that would be expected from lowering sodium intake by 1840 mg/day, the following procedure was followed, assuming that 60% of hypertensive patients were on a single antihypertensive drug and that 40% of patients were treated with two or more antihypertensive drugs (28). Given that the average reduction in BP with one drug was 9.1 mmHg in SBP and 5.5 mmHg in DBP, and 14.6 mmHg in SBP and 8.6 mmHg in DBP with two drugs, a weighted average using 60% on one drug and 40% on two drugs would result in an average decrease of 11.3 mmHg in SBP and 6.74 mmHg in DBP. This provided an estimate of the increase in BP of those with 'treated and controlled' hypertension if their antihypertensive therapy was withdrawn. The average reduction in BP expected from a reduction in sodium consumption (SBP 5.06 mmHg, DBP 2.7 mmHg) was then subtracted to estimate how many patients would remain controlled (ie, BP of less than 140/90 mmHg) on a sodium-restricted diet alone. This resulted in adding 6.24 mmHg to the SBP and 4.04 mmHg to the DBP, and observing how many treated hypertensive patients would still be controlled after withdrawing drug therapy (23%) and computing the resulting savings only on these individuals, assuming that the previously treated and controlled individuals now uncontrolled would resume their drug therapy.

The Canadian Community Health Survey

Current estimates of aware hypertensive patients are available from the Canadian Community Health Survey (CCHS, cycle 2.1). This cross-sectional survey randomly sampled Canadians from all provinces in Canada in 2003 (29,30). The CCHS did not measure BP and, thus, the prevalence of actual hypertension; treatment and control rates for hypertension also cannot be determined from this survey. However, for the current cost reduction estimates in the present study, the most recent prevalence of reported hypertension from the CCHS (n=4,451,000, 18.7%) was used, reduced by 14.9% (n=3,787,801) to take into account those who might have already been on a sodium-restricted diet, as estimated from the previous CHHS data.

National data on physician office visits

To determine the number of office visits made to office-based physicians occurring on an annual basis for hypertension, and the amount and costs of drugs used to control hypertension, data were obtained from IMS Canada. IMS Canada collects data on office visits based on a sample of physicians in different regions of Canada. Physicians record the main reason for the office visit and the indications for any drug prescriptions provided, but no patient identification is recorded. Hypertension was the leading diagnosis associated with office-based physician visits in 2003, accounting for 20,365,000 visits (31). The cost of a routine office visit to a primary care physician (intermediate assessment A007) in 2003 was $27.30 (32).

TABLE 1
Potential direct cost savings* after sodium restriction of 1840 mg/day in Canadians with hypertension

	No modification	Per cent reduction and estimated cost reductions due to reduced dietary sodium	
Cost category	Costs, $	%	Cost reductions, $
Physician	555,964,000	6.5	36,138,000
Pharmaceuticals†	1,684,561,000	23.0	387,449,000
Laboratory	92,422,000	6.5	6,007,000
Total	2,332,947,000		429,594,000

**Cost estimates rounded to the 1000; †Data obtained from reference 37*

Laboratory data

There is no published study that estimates the use of laboratory services occurring as a result of the management of patients with hypertension. As such, laboratory costs were estimated from Ontario data as follows. Prevalent cases of hypertension for patients 35 years of age and older were identified using the rule of two Ontario Health Insurance Plan (OHIP) physician billings for hypertension (International Classification of Diseases-9 code 401.x to 405.x) within a three-year period starting from April 1991 to March 2001 (33). Patients whose first OHIP bill appeared in fiscal year 2001 were considered incident cases and were excluded. To keep the analysis of laboratory test use to those patients with uncomplicated hypertension, patients with diabetes according to the Ontario Diabetes Database (34) and patients with the comorbid conditions of myocardial infarction or angina, heart failure, arrhythmias, renal disease, liver disease including esophageal varices, transient ischemic attack or stroke, hyperthyroidism or migraines, according to the presence of an OHIP billing code in the prior three years or Canadian Institute for Health Information hospitalization discharge abstracts in the prior four years were excluded. Patients who were hospitalized or died in the fiscal year 2001 were also excluded.

Laboratory tests that were likely performed in the course of outpatient management of patients with hypertension (eg, potassium, sodium, creatinine, glucose, lipids, urinalysis, complete blood count and electrocardiograms) were determined based on OHIP billings for patients with uncomplicated hypertension as noted above. OHIP includes claims data for laboratory tests performed in all outpatient labs in Ontario, but excludes tests performed in-hospital (35,36). Costs for tests were based on the amount paid by OHIP.

Cost estimates

To estimate the potential cost savings that may result from a population-based intervention to reduce sodium intake, the impacts on direct health care costs were assessed, including physician visits, antihypertensive drug use and laboratory costs, which were all derived from data between 2001 and 2003, and are reported without inflation. Because there were 20,365,000 physician visits at an estimated cost of $27.30 per visit (2003), the total physician visits cost estimate was $555,964,000 (Table 1). In the analysis, it was assumed that drug-treated patients who became normotensive as a result of sodium restriction (6.5%) would no longer visit a physician for hypertension. While this may not be completely accurate in the short-term, because patients may continue to visit their physicians at similar rates, it is likely to be a reasonable assumption over the longer term. Aware hypertensive patients who were not treated in the primary analysis were not included, but the related cost was included in the secondary analysis.

TABLE 2
Estimated prevalence, awareness, and control of hypertension in Canada, before and after a hypothetical reduction in sodium intake of 1840 mg/day based on the Canadian Heart Health Surveys

Hypertension category	No modification, n* (%)	With decreased sodium intake, n (%)	Change, n	Absolute change, %	Relative change, %
Prevalence	3,547,000 (19.4)	2,469,000 (13.5)	–1,078,000	–5.9	–30.3
Treated, controlled	412,000 (11.6)	531,000 (21.5)	119,000	9.9	84.8
Treated, not controlled	612,000 (17.3)	493,000 (20.0)	–119,000	–2.7	–15.6
Not treated, not controlled	796,000 (22.5)	500,000 (20.3)	–296,000	–2.2	–9.8
Not aware	1,723,000 (48.6)	945,000 (38.3)	–778,000	–10.4	–21.3

*Treatment defined as with drugs only; individuals reporting salt reduction were removed from the analyses. Figures may not add up due to rounding and may differ from previous articles due to these restrictions. *Population estimates, rounded to the 1000*

TABLE 3
Estimated prevalence and proportion of treated hypertensive patients staying controlled after removing drug treatment and applying a reduction in dietary sodium of 1840 mg/day based on the Canadian Heart Health Surveys

Hypertension category	No modification, n* (%)	Still controlled with decreased sodium intake, after removing drug treatment, n (%)	Proportion of all treated hypertensive patients staying controlled,%
Treated, controlled	412,000 (11.6)	235,000 (6.6)	23.0
All treated hypertensive patients	1,023,000 (28.8)		

*Treatment defined as with drugs only; individuals reporting salt reduction were removed from the analyses. Figures differ from previous articles due to these restrictions. *Population estimates, rounded to the 1000*

With respect to the potential cost savings on antihypertensive drugs, first the direct costs of antihypertensive drug therapies in Canada using IMS data were estimated, which are based on prescription data obtained from approximately 70% of retail pharmacies in Canada (37). (The costs of drug therapies from IMS are estimated dollar values of prescriptions dispensed from Canadian retail pharmacies, which include markup and professional fees.) Antihypertensive drug therapy is one of the most expensive categories. The total cost of BP-lowering therapy for an antihypertensive indication in 2003 was estimated to be $1,684,561,000 (31). To estimate the potential savings in drug therapy, this cost was reduced by the proportion of treated hypertensive patients who would remain normotensive with a lower sodium intake after stopping their antihypertensive drugs (23%). As with physician costs, these savings may not occur immediately, but would accrue over time as physicians adjust antihypertensive drug therapy to reach or maintain target BP levels.

To determine the total laboratory costs per year required in the management of patients with hypertension, the average laboratory costs per person per year were estimated for the OHIP patient cohort noted above. Among the 813,233 prevalent cases of hypertension 35 to 64 years of age and older identified in the OHIP 2001 hypertension cohort who did not have cardiovascular complications, there were 241,900 electrocardiograms with 243,195 interpretations, 548,588 complete blood counts, 292,332 tests for urinalysis, 513,328 tests for glucose, 458,940 tests for total cholesterol, 444,289 tests for triglyceride concentration, 409,769 tests for high-density lipoprotein cholesterol, and 345,335 sodium, 383,710 potassium and 524,505 creatinine blood level measurements, for a total cost of $19,846,811/year, or $24.40/hypertensive person/year. Total laboratory costs per year in Table 1 (3,787,801×$24.40) and cost reductions were therefore estimated using the CCHS population of aware hypertensive patients who would no longer have hypertension while following a diet lower in sodium.

RESULTS

Changes in the prevalence of hypertension, awareness treatment and control rates

Hypothetical changes in the actual prevalence, awareness and control of hypertension as estimated in the CHHS after reducing sodium intake by 1840 mg/day are reported in Table 2. The prevalence of hypertension would decrease by 30.3%, from 19.4% to 13.5%, resulting in 1,078,000 hypertensive patients being removed from the hypertensive category.

The greatest relative gain would be in the treated and controlled category, with an 84.8% relative increase (119,000 more individuals treated and controlled), from 11.6% to 21.5% of all hypertensive patients. The other hypertension categories would also gain, and the percentage of unaware hypertensive patients would decrease by 21.3%. Among aware hypertensive patients (total of 1,820,000), the additional 119,000 hypertensive patients being controlled (6.5%) would no longer require the current level of physician visits and laboratory tests. This percentage (6.5%) was used to estimate the cost savings among aware hypertensive patients (Table 1).

Table 3 reports the estimated prevalence and proportion of hypertensive patients staying controlled after hypothetically removing drug treatment and applying a reduction in dietary sodium intake of 1840 mg/day. As noted above, after removal of the antihypertensive medications, mean BP would increase by 6.24 mmHg (systolic) and 4.04 mmHg (diastolic). Despite this relative increase, 235,000 individuals would remain in the treated and controlled category, without requiring drugs. This may result in 23% of all treated and controlled hypertensive patients being taken off therapy.

Cost savings associated with dietary sodium restriction

The estimated direct cost savings after a sodium intake reduction of 1840 mg/day in individuals with hypertension are presented by cost category in Table 1. The direct costs of managing hypertension in Canada, due to physician visits, pharmaceutical and laboratory costs were estimated to be approximately $2.33 billion/year. The estimated savings that may result from a population-based intervention of sodium intake restriction would be approximately $430 million/year (18% decrease). An additional $108 million cost savings could be achieved through reduced physician visits and laboratory costs if it is assumed, from the CHHS, that the 16.3% of aware

hypertensive patients who were not treated and became controlled after sodium intake reduction did not require further laboratory tests and physician visits. Savings on antihypertensive medications constitute the majority of cost savings (90%).

DISCUSSION

The present study shows the potential to substantially reduce the prevalence of hypertension, improve the management of hypertension and reduce health costs in Canada by reducing average population dietary intakes of sodium. The reduction in daily sodium intake of 1840 mg is estimated to result in more than one million fewer Canadians with hypertension, an 85% improvement in the rate of treated and controlled hypertension in Canada, 1.3 million fewer physician office visits for Canadians per year (a 6.5% reduction), and a cost savings from drugs, office visits and laboratory testing directly related to hypertension of approximately $430 million per year, or more than half a billion Canadian dollars per year if we also include aware but not treated hypertensive patients in our estimates. The extent of reduction in dietary sodium that is necessary to result in these benefits is consistent with dietary recommendations adopted by Health Canada (22).

Approximately 77% of the sodium in Canadian diets is added during processing by the food industry, 11% occurs naturally in food and 12% is added by Canadians in cooking or at the table (23). Because of the difficulty in reducing dietary sodium intake through individual counselling (38) or policies relying on voluntary compliance by companies, the WHO has indicated that government regulation to reduce the amount of sodium added to food by food industries is the most effective mechanism (5). A reduction in dietary sodium intake of more than 40% was achieved in Finland (39) by a combination of regulation, policies, and health care professional and public education. The WHO-advocated approach to reducing dietary sodium through a reduction in sodium additives to food has been supported by many public health and scientific bodies (18-21,40).

While our study presents some convincing data, there are several limitations. The estimates of hypertension prevalence, treatment and control rates were based on the CHHS data (4). These 10 provincial surveys were conducted between 1986 and 1992, and may not be totally relevant to the current situation. Unfortunately, more recent data on BP measurements in Canada do not exist. We also removed from our estimates of hypertension prevalence those individuals who mentioned being advised to reduce their dietary sodium intake, regardless of whether they actually did. We did not include those patients who used exclusively nonpharmacological treatment as treated individuals. This conservative approach resulted in different and lower prevalence estimates than previous publications (4,3), but was necessary to reduce other potential biases. Our data also likely represent underestimates of the impacts of reducing dietary sodium intake in Canada, because newer Canadian and American data have shown increases in the prevalence, treatment and diagnosis of hypertension (30,41). It is therefore likely that our study has underestimated the number of cases of hypertension that would be reduced or prevented by a reduction in dietary sodium and has subsequently underestimated the associated cost savings.

Our study estimated the reduction in BP from the 2006 Cochrane Collaboration meta-analysis (24). This estimate of reduction in BP (5.06/2.7 mmHg) is similar to the estimate in the recent National Institute for Clinical Evaluation (NICE) meta-analysis (–4.7/–2.5 mmHg) (15). However, the data are from clinical trials and may not represent the effects of sodium reduction at a population level. Nevertheless, in Finland (39), a comprehensive program resulted in systematic reductions in dietary sodium, and subsequently, large reductions in population BP and cardiovascular disease were observed. The population decreases in BP in Finland were more than 10 mmHg (systolic and diastolic) while dietary sodium intake was reduced by 2400 mg/day. In a meta-analysis of randomized controlled trials (42), an average reduction of sodium by 2400 mg/day reduced BP by an average of 11.2/6.4 mmHg.

The true magnitude of cost savings associated with reduction in sodium intake may vary based on a number of factors that are presently uncertain. Therefore, it should be acknowledged that these are estimates, with some unknown degree of variation to be expected. Limitations of our costing analysis include the assumption that a reduction in the prevalence of hypertension and its treatment would result in a linear reduction in physician visits, antihypertensive drug use and laboratory costs. Furthermore, some laboratory and physician visit costs that we attributed to hypertension may occur in patients with normal BP and, hence, would not be avoided by becoming normotensive. However, if dietary sodium had historically been 1840 mg/day lower than it currently is, our study indicates that there would be 1,078,000 fewer hypertensive patients in Canada who would not have the incurred costs associated with the diagnosis and management of hypertension. In our primary analysis, we conservatively only considered the cost savings associated with fewer visits to physicians by 119,000 patients who were on drug therapy, but could have been controlled by reducing sodium intake alone. Costs avoided by reduced visits in patients aware of their hypertension but who were not on drug therapy and became normotensive during reduced sodium intake were not included in the primary analysis; inclusion of such patients could have increased our estimate of cost savings by more than $100 million/year. We also excluded the higher laboratory costs associated with the initial diagnosis of hypertension and in testing those with hypertension and comorbidity. Of note, the present study estimated only the direct consequences and costs associated with the reduction in hypertension related to a reduced dietary sodium intake. Patients diagnosed with hypertension may feel less well and have increased work absenteeism (43), and if BP is not well-controlled, those with hypertension will have an increase in cardiovascular events (44). Additional potential cost savings that may be substantive but were not included in our analysis are the costs of managing premature illnesses that occur as a result of hypertension. Therefore, our estimates of cost savings are likely to be conservative. We had not estimated the potential cost of implementing a population-based approach to reducing sodium additives to food. The cost of counselling patients to avoid sodium additives could be considerable and has limited effectiveness (38). Therefore, many scientific and public health organizations recommend that population changes in sodium intake be implemented by imposing regulations and policies affecting the addition of sodium to foods by the food sector, coupled with public education programs (5,18,19).

There is concern that individual variation in BP response to reduction in sodium intake (sodium sensitivity) makes

population reductions in dietary sodium inappropriate. In very short-term studies, only a small proportion of those with normal BP have a substantive reduction in BP with reduced dietary sodium (45). While a full discussion of sodium sensitivity is beyond the scope of the present article, the issue has been reviewed in the creation of health policy by many well-established scientific and public health organizations (18,19,22). Meta-analyses (15,24,46) have found reductions in average BP in clinical trials involving normotensive infants, children and adults, and hypertensive adults when dietary sodium intake is lowered. While there is clear individual variability in the reduction in BP, this reduction is normally distributed, and much of the variability is explained by the intrinsic variation in BP with 'nonresponders' to sodium on one assessment often responding when reassessed (22,47). Although not clinically intuitive, seemingly small population changes in BP are associated with large, beneficial changes in cardiovascular events because there is a reduction in cardiovascular risk in the normotensive population (7,48). For example, a 5 mmHg reduction in SBP in a population is predicted to result in a 14% reduction in stroke death, a 9% reduction in coronary artery disease-related death and a 7% reduction in total mortality (7). Larger reductions in dietary sodium additives result in larger reductions in BP (24), suggesting that the lack of response to sodium reduction in some individuals is in part related to the extent sodium additives reduced in the diet. Sodium sensitivity is topical in basic and genetic hypertension research. However, the implications of 'sodium sensitivity', as currently defined and understood, are not viewed as having public health or clinical importance by major scientific and public health organizations (18,19,22).

It has also been hypothesized that the increases in BP associated with sodium additives are safe and not associated with increased cardiovascular events (49). However, increased BP is estimated to be the leading risk for death in the world (1), and there are strong (log) linear relations between BP and cardiovascular complications (44). Our study has estimated that 30% of hypertension in Canada is associated with high dietary sodium. National and international scientific organizations examining the evidence of investigative groups around the world have found compelling associations between diets high in sodium and hypertension, and have concluded that high sodium diets are not safe (18-22). More recently, a meta-analysis of patients in the Trials Of Hypertension Prevention (TOHP) trials (50) followed long-term found a reduction in cardiovascular events in those randomly assigned to sodium reduction. A cluster randomized trial published in 2006 (51) that substituted one-half of the regular dietary sodium with potassium was associated with increased longevity and reduced cardiovascular complications. Most hypertension guidelines also recommend sodium-reduced diets (11-14). Unfortunately, summaries of the detailed reports of recognized scientific bodies are not published in easily accessed clinical journals.

As governments look to enhancing the health of Canadians and reducing health care expenditures, they need to consider reducing the amount of sodium additives in food. Our study indicates that a significant reduction in hypertension and health care cost savings may result from such an approach. Guidelines alone, such as those of the Canadian Hypertension Education Program, are unlikely to be effective.

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REFERENCES

1. Ezzati M, Lopez AD, Rodgers A, Vander Hoorn S, Murray CJLM; Comparative Risk Assessment Collaborating Group. Selected major risk factors and global and regional burden of disease. Lancet 2002;360:1347-60.
2. Lawes CMM, Vander Hoorn S, Law MR, Elliott P, MacMahon S, Rodgers A. Blood pressure and the global burden of disease 2000. Part 1: Estimates of blood pressure levels. J Hypertens 2006;24:413-22.
3. Wolf-Maier K, Cooper RS, Banegas JR, et al. Hypertension prevalence and blood pressure levels in 6 European countries, Canada, and the United States. JAMA 2003;289:2363-9.
4. Joffres MR, Ghadirian P, Fodor JG, Petrasovits A, Chockalingam A, Hamet P. Awareness, treatment, and control of hypertension in Canada. Am J Hypertens 1997;10:1097-102.
5. World Health Organization. The world health report 2002 – reducing risks, promoting healthy life. Geneva, Switzerland. <www.who.int/whr/2002/en> (Version current at March 9, 2007).
6. Mohan S, Campbell N, Chockalingam A. Management of hypertension in low and middle income countries: Challenges and opportunities. Prev Control 2005;1:275-84.
7. Whelton PK, He J, Appel LJ, et al; National High Blood Pressure Education Program Coordinating Committee. Primary prevention of hypertension: Clinical and public health advisory from The National High Blood Pressure Education Program. JAMA 2002;288:1882-8.
8. Kearney PM, Whelton M, Reynolds K, Muntner P, Whelton PK, He J. Global burden of hypertension: Analysis of worldwide data. Lancet 2005;365:217-23.
9. Chockalingam A, Balaguer-Vintro I. Impending Global Pandemic of Cardiovascular Diseases. Barcelona: Prous Science, 1999.
10. Vasan RS, Beiser A, Seshadri S, et al. Residual lifetime risk for developing hypertension in middle-aged women and men: The Framingham Heart Study. JAMA 2002;287:1003-10.
11. Khan NA, McAlister FA, Rabkin SW, et al; Canadian Hypertension Education Program. The 2006 Canadian Hypertension Education Program recommendations for the management of hypertension: Part II – therapy. Can J Cardiol 2006;22:583-93.
12. Chobanian AV, Bakris GL, Black HR, et al; National Heart, Lung, and Blood Institute Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure; National High Blood Pressure Education Program Coordinating Committee. The seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: The JNC 7 report. JAMA 2003;289:2560-72. (Erratum in 2003;290:197).
13. European Society of Hypertension-European Society of Cardiology Guidelines Committee. 2003 European Society of Hypertension-European Society of Cardiology guidelines for the management of arterial hypertension. J Hypertens 2003;21:1011-53. (Errata in 2003;21:2203-4, 2004;22:435).
14. Williams B, Poulter NR, Brown MJ et al; British Hypertension Society. Guidelines for management of hypertension: Report of the fourth working party of the British Hypertension Society, 2004 – BHS IV. J Hum Hypertens 2004;18:139-85.
15. Dickinson HO, Mason JM, Nicolson DJ, et al. Lifestyle interventions to reduce raised blood pressure: A systematic review of randomized controlled trials. J Hypertens 2006;24:215-33.
16. Advisory Board of the Second International Heart Health Conference. The Catalonia Declaration. Investing in heart health. 1995:1-85. <www.internationalhearthealth.org/Publications/catalonia1995.pdf> (Version current at March 9, 2007).

17. Advisory Board of the International Heart Health Conference. The Victoria Declaration on Heart Health. 1992:1-56. <www.internationalhearthealth.org/Publications/victoria_eng_1992.pdf> (Version current at March 9, 2007).
18. Scientific Advisory Committee on Nutrition. Salt and Health. 2003:1-134. <www.food.gov.uk/multimedia/pdfs/saltandhealth0503.pdf> (Version current at March 9, 2007).
19. American Public Health Association. Reducing sodium content in the American diet. American Public Health Association – Association News 2002. 2002 Policy statements: 5-6.
20. Appel LJ, Brands MW, Daniels SR, Karanja N, Elmer PJ, Sacks FM; American Heart Association. Dietary approaches to prevent and treat hypertension: A scientific statement from the American Heart Association. Hypertension 2006;47:296-308.
21. Council on Science and Public Health. Report 10 of the Council on Science and Public Health (A-06). Promotion of Healthy Lifestyles I: Reducing the population burden of cardiovascular disease by reducing sodium intake. American Medical Association, 2006.
22. Panel on Dietary Reference Intakes for Electrolytes and Water, Standing Committee on the Scientific Evaluation of Dietary Reference Intakes. Dietary Reference Intakes for Water, Potassium, Sodium, Chloride and Sulfate. Washington: National Academies Press, 2004:1-640.
23. Mattes RD, Donnelly D. Relative contributions of dietary sodium sources. J Am Coll Nutr 1991;10:383-93.
24. He FJ, MacGregor GA. Effect of longer-term modest salt reduction on blood pressure. Cochrane Database Syst Rev 2004;(3):CD004937. (Updated in 2006)
25. Joffres MR, Hamet P, Rabkin SW, Gelskey D, Hogan K, Fodor G. Prevalence, control and awareness of high blood pressure among Canadian adults. Canadian Heart Health Surveys Research Group. CMAJ 1992;146:1997-2005.
26. MacLean DR, Petrasovits A, Nargundkar M, et al. Canadian heart health surveys: A profile of cardiovascular risk. Survey methods and data analysis. Canadian Heart Health Surveys Research Group. CMAJ 1992;146:1969-74.
27. Law MR, Wald NJ, Morris JK, Jordan RE. Value of low dose combination treatment with blood pressure lowering drugs: Analysis of 354 randomised trials. BMJ 2003;326:1427-34.
28. Tu K, Campbell NRC, Durong-Hua M, McAlister FA. Hypertension management in the elderly has improved: Ontario prescribing trends, 1994 to 2002. Hypertension 2005;45:1113-8.
29. Beland Y. Canadian community health survey – methodological overview. Health Rep 2002;13:9-14.
30. Onysko J, Maxwell C, Eliasziw M, Zhang J, Johansen H, Campbell NR; Canadian Hypertension Education Program. Large increases in hypertension diagnosis and treatment in Canada after a healthcare professional education program. Hypertension 2006;48:853-60.
31. IMS Health Canada. Canadian Disease and Therapeutic Index, 2003.
32. Ontario Ministry of Health and Long-Term Care. Schedule of benefits: Physician services under the Health Insurance Act. Toronto, 2003.
33. Tu K, Campbell NRC, Chen Z, Cauch-Dudek KJ, McAlister FA. Validation of administrative databases in identifying patients with hypertension. Open Med 2007. (In press)
34. Hux JE, Ivis F, Flintoft V, Bica A. Diabetes in Ontario. Determination of prevalence and incidence using a validated administrative data algorithm. Diabetes Care 2002;25:512-6.
35. van Walraven C, Goel V, Chan B. Effect of population-based interventions on laboratory utilization: A time-series analysis. JAMA 1998;280:2028-33. (Erratum in 2000;283:481).
36. van Walraven C, Raymond M. Population-based study of repeat laboratory testing. Clin Chem 2003;49:1997-2005.
37. IMS Health Canada, Canadian CompuScript Audit, 2003.
38. Hooper L, Bartlett C, Davey Smith G, Ebrahim S. Systematic review of long term effects of advice to reduce dietary salt in adults. BMJ 2002;325:628-37.
39. Karppanen H, Mervaala E. Sodium intake and hypertension. Prog Cardiovasc Dis 2006;49:59-75.
40. Carruthers SG, Larochelle P, Haynes RB, Petrasovits A, Schiffrin EL. Report of the Canadian Hypertension Society Consensus Conference: 1. Introduction. CMAJ 1993;149:289-93.
41. Hajjar I, Kotchen TA. Trends in prevalence, awareness, treatment, and control of hypertension in the United States, 1988-2000. JAMA 2003;290:199-206.
42. He FJ, MacGregor GA. How far should salt intake be reduced? Hypertension 2003;42:1093-9.
43. Haynes RB, Sackett DL, Taylor DW, Gibson ES, Johnson AL. Increased absenteeism from work after detection and labeling of hypertensive patients. N Engl J Med 1978;299:741-4.
44. Lewington S, Clarke R, Qizilbash N, Peto R, Collins R; Prospective Studies Collaboration. Age-specific relevance of usual blood pressure to vascular mortality: A meta-analysis of individual data for one million adults in 61 prospective studies. Lancet 2002;360:1903-13. (Erratum in 2003;361:1060).
45. Hollenberg NK. The influence of dietary sodium on blood pressure. J Am Coll Nutr 2006;25:240S-6S.
46. He FJ, MacGregor GA. Importance of salt in determining blood pressure in children: Meta-analysis of controlled trials. Hypertension 2006;48:861-9.
47. Obarzanek E, Proschan MA, Vollmer WM, et al. Individual blood pressure responses to changes in salt intake: Results from the DASH-Sodium trial. Hypertension 2003;42:459-67.
48. Cook NR, Cohen J, Hebert P, Taylor JO, Hennekens CH. Implications of small reductions in diastolic blood pressure for primary prevention. Arch Intern Med 1995;155:701-9.
49. The Salt Institute. <www.saltinstitute.org> (Version current at March 12, 2007).
50. Cook NR, Cutler JA, Obarzanek E, et al. The effects of dietary sodium reduction on cardiovascular disease: Long-term follow-up of the Trials of Hypertension Prevention. J Hypertens 2006;24:S141.
51. Chang H-Y, Hu Y-W, Yue C-SJ, et al. Effect of potassium-enriched salt on cardiovascular mortality and medical expenses of elderly men. Am J Clin Nutr 2006;83:1289-96.