## Hypertension Prevalence, Awareness, Treatment, and Control in National Surveys from England, the USA, and Canada, and Correlation with Stroke and Ischemic Heart Disease Mortality

| Journal: | BMJ Open |
| :---: | :---: |
| Manuscript ID: | bmjopen-2013-003423 |
| Article Type: | Research |
| Date Submitted by the Author: | 16-Jun-2013 |
| Complete List of Authors: | Joffres, Michel; Simon Fraser University, Faculty of Health Sciences Falaschetti, Emanuela; School of Public Health, Imperial College London, Imperial Clinical Trial Unit <br> Gillespie, Cathleen; Centers for Disease Control and Prevention, Division for Heart Disease and Stroke Prevention <br> Robitaille, Cynthia; Public Health Agency of Canada, Centre for Chronic Disease Prevention <br> Loustalot, Fleetwood; Centers for Disease Control and Prevention, Division for Heart Disease and Stroke Prevention <br> Poulter, Neil; Imperial College London, International Centre for Circulatory Health <br> Mcalister, Finlay; University of Alberta Canada, Medicine <br> Johansen, Helen; University of Ottawa, <br> Baclic, Oliver; Public Health Agency of Canada, <br> Campbell, Norm; University of Calgary, Libin Cardiovascular Institute of Alberta |
| <b>Primary Subject Heading</b>: | Public health |
| Secondary Subject Heading: | Cardiovascular medicine, Epidemiology, Health policy |
| Keywords: | Hypertension < CARDIOLOGY, Stroke < NEUROLOGY, Myocardial infarction < CARDIOLOGY, EPIDEMIOLOGY, PUBLIC HEALTH |

SCHOLARONE
Manuscripts
Manuscripts

# Hypertension Prevalence, Awareness, Treatment, and Control in National Surveys from England, the USA, and Canada, and Correlation with Stroke and Ischemic Heart Disease Mortality 

Michel Joffres, professor of epidemiology ${ }^{1}$, Emanuela Falaschetti, research fellow in clinical trial statistics ${ }^{2}$, Cathleen Gillespie, senior statistician ${ }^{3}$, Cynthia Robitaille, epidemiologist ${ }^{4}$, Fleetwood Loustalot, epidemiologist ${ }^{3}$, Neil Poulter, professor ${ }^{5}$, Finlay A. McAlister, professor ${ }^{6}$, Helen Johansen, adjunct professor ${ }^{7}$, Oliver Baclic, medical advisor ${ }^{8}$, Norm Campbell, professor ${ }^{9}$
${ }^{1}$ Faculty of Health Sciences, Simon Fraser University, Burnaby, BC V5A 1S6, Canada.
${ }^{2}$ Imperial Clinical Trial Unit, School of Public Health, Imperial College London, St Mary’s Campus, Norfolk Place, W2 1PG London UK
${ }^{3}$ Division for Heart Disease and Stroke Prevention, Centers for Disease Control and Prevention, 4770 Buford Hwy NE, Mailstop F-72, Atlanta GA 30341
${ }^{4}$ Centre for Chronic Disease Prevention, Public Health Agency of Canada 785 Carling Avenue, A.L. 6806A, Ottawa, Ontario, Canada, K1A 0K9
${ }^{5}$ International Centre for Circulatory Health, Imperial College London, 59-61 North Wharf Road, London W2 1PG, UK
${ }^{6}$ Division of General Internal Medicine, University of Alberta Hospital 8440112 Street, Edmonton, Alberta T6G 2R7, Canada
${ }^{7}$ Department of Community Medicine and Epidemiology, University of Ottawa, Epidemiology \& Community Medicine, Room 3105, 451 Smyth Road, Ottawa, Ontario, Canada, K1H 8M5
${ }^{8}$ Public Health Agency of Canada, 130 Colonnade Rd, Ottawa, K1A0K9
${ }^{9}$ Departments of Medicine, Community Health Sciences and of Physiology and Pharmacology, Libin Cardiovascular Institute, University of Calgary, Canada Libin Cardiovascular Institute of Alberta, University of Calgary, 3280 Hospital Drive NW, Calgary Alberta, T2N 4Z6

Correspondance to: Michel Joffres mjoffres@sfu.ca

The Corresponding Author has the right to grant on behalf of all authors and does grant on behalf of all authors, an exclusive licence (or non exclusive for government employees) on a worldwide basis to the BMJ Publishing Group Ltd to permit this article (if accepted) to be published in BMJ editions and any other BMJPGL products and sublicences such use and exploit all subsidiary rights, as set out in our licence.

Competing Interests. All authors have completed the Unified Competing Interest form atwww.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; Dr. Poulter reports grants from Pfizer, grants from Hypertension Trust and personal fees from various Pharma companies, other from Servier, outside the submitted work; Dr Norm Campbell receives for salary support for a HSFC CIHR Chair in Hypertension Prevention and Control; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval was not required for these secondary analyses since all the original studies had their own ethical approval process.

Details of funding - No specific funding was provided for this study. Funding for NHANES comes from two primary sources: direct funding through the NCHS base budget and reimbursable funding from collaborating agencies; The Health Survey for England was funded by the National Health Centre; Health Canada and the Public Health Agency of Canada supported Statistics Canada in obtaining federal funding for for the Canadian Health Measures Survey. Other sources of support: FAM is supported by an Alberta Innovates Health Solutions Senior Health Scholar Award and the University of Alberta/Capital Health Chair in Cardiovascular Outcomes Research. NC holds the Heart and Stroke Foundation of Canada CIHR Chair in Hypertension Prevention and Control. NP is grateful for support from the NIHR Biomedical Research funding scheme and the NIHR Senior Investigator Award. Funding of the original surveys;

Statement of independence of researchers from funders - The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention, the Public Health Agency of Canada or the UK Department of Health.

Data sharing statement. All the authors had access to the original tables from the different studies. There is no additional data available.

Author's Contributions: Michel Joffres, Emanuela Falaschetti , Cathleen Gillespie, Cynthia Robitaille contributed to the data analysis, interpretation and writing.
Fleetwood Loustalot, Neil Poulter, Finlay A. McAlister, Helen Johansen, Oliver Baclic, and Norm Campbell contributed to the data interpretation and writing.

## Article Summary

1) Article focus

- Comparison of hypertension prevalence, awareness, treatment, and control in 3 National studies, England, USA, and Canada
- Correlation with stroke and ischemic heart disease mortality

2) Key messages

- Important variation by country
- Strong relationship between hypertension indicators and stroke mortality
- Gaps in the management of hypertension

3) Strengths and limitations

- Strengths
- National population data
- Detailed data on hypertension characteristics
- Strong correlation with meaningful outcome, mortality
- Limitations
- Data from England from 2006, but provide an important basis for measuring progress (current data not yet available)
- Limited to 3 countries
- Ecological correlation with mortality that excludes looking at confounders


#### Abstract

Objective Comparison of recent national survey data on prevalence, awareness, treatment and control of hypertension in England, the USA and Canada, and correlation of these parameters with each country stroke and ischemic heart disease (IHD) mortality.


Methods Non-instutionalized population surveys from England (2006), the USA (2007-2010) and Canada (2007-2009) using standardized protocols and devices. Analysis included individuals age 20-79 years. Stroke and IHD mortality rates were plotted against country specific prevalence data.

Results Mean systolic blood pressure (SBP) was higher in England than in the USA and Canada in all age-gender groups. Mean diastolic blood pressure (DBP) was similar in the three countries before age 50 and then fell more rapidly in the USA and was the lowest in the USA. Only $34 \%$ had a BP under $140 / 90 \mathrm{mmHg}$ in England, compared with $50 \%$ in the USA and $66 \%$ in Canada. Prehypertension and stage 1 and 2 hypertension prevalence figures were the highest in England. Hypertension prevalence ( $\geq 140 \mathrm{mmHg}$ SBP and/or $\geq 90 \mathrm{mmHg}$ DBP) was lower in Canada (19.5\%) than in the USA (29\%) and England (30\%). Hypertension awareness was higher in both the USA (81\%) and Canada (83\%), than in England (65\%). England also had lower levels of hypertension treatment (51\%; USA 74\%; Canada 80\%) and control (< 140/90 mmHg; 27\%; USA 53\%; Canada 66\%). Canada had the lowest Stroke and IHD mortality rates, England the highest, and rates were inversely related to the mean SBP in each country and strongly related to blood pressure indicators, the strongest relationship being between low hypertension awareness and stroke mortality.

Conclusion While current prevention efforts in England should result in future improved figures, these data still show important gaps in the management of hypertension in these countries with consequences on stroke and IHD mortality.

## Introduction

Increased blood pressure is the leading risk factor for premature death, stroke, and heart disease worldwide. ${ }^{1}$ In the year 2000, the world was estimated to have close to 1 billion people with hypertension and predicted an increase to 1.56 billion by 2025.2 ${ }^{2}$ The global economic burden of increased blood pressure was estimated to consume 370 billion US \$ worldwide and $10 \%$ of health care expenditures. ${ }^{3}$ Usual blood pressure is strongly and directly related to vascular and overall mortality without evidence of a threshold down to at least $115 / 75 \mathrm{mmHg}^{4}$ with small changes in blood pressure resulting in substantial changes in vascular disease. ${ }^{5}$

Based on clinical and population research, increased blood pressure, hypertension and hypertension related complications are largely preventable. Lifestyle changes can lower blood pressure and prevent hypertension while antihypertensive drug therapy can effectively reduce the cardiovascular events attributed to hypertension. ${ }^{1-6}$ Nevertheless, most people with hypertension worldwide are not effectively treated and controlled to recommended blood pressure targets. ${ }^{7}$ There are few national programs to serve as models for prevention and control of hypertension and few countries have embarked on national hypertension prevention and control programs. The United States (USA) blood pressure education program was established in $1972{ }^{8}$, while Canada (2000) and England (2004) have more recent initiatives. ${ }^{9,10}$ This manuscript compares recent data on prevalence, awareness, treatment and control of hypertension in England, the USA and Canada and correlates these hypertension-related parameters in the three countries to mortality from stroke and ischemic heart disease (IHD).

## Methods

Survey methods used in England, the USA, and Canada are summarized in Table 1. Detailed methodology for each survey is available elsewhere. ${ }^{11-13}$ Briefly, each survey is a representative sample of each country's non-institutionalized population and uses standardized protocols and
devices. While the England (2006) and Canada (2007-2009) surveys used automatic oscillometric devices, the USA (2007-2010) survey used mercury wall sphygmomanometer models. The number of blood pressure measurements available for analysis varied by count of blood pressure measures and survey protocols (Table 1).

In these analyses, hypertension was defined as a mean systolic blood pressure (SBP) $\geq 140 \mathrm{mmHg}$ or a mean diastolic blood pressure (DBP) $\geq 90 \mathrm{mmHg}$ or a respondent self-report of medication to lower blood pressure. Pre-hypertension (SBP 120-139 mmHg or DBP 80-89 mmHg), stage 1 (SBP $140-159 \mathrm{mmHg}$ or DBP $90-99 \mathrm{mmHg}$ ), and stage 2 (SBP $\geq 160 \mathrm{mmHg}$ or DBP $\geq 100 \mathrm{mmHg}$ ) hypertension were defined according to the Seventh Report of the Joint National Committee on the Prevention, Detection, Evaluation and Treatment of High Blood Pressure (JNC 7) definitions. ${ }^{6}$ Prevalence, awareness, treatment, control and awareness of hypertension were defined using commonly recognized standards. Prevalence was defined as SBP $\geq 140$ or DBP $\geq 90$ or currently taking medication to lower their blood pressure. Awareness was defined by self-report and included having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during pregnancy (England), medication to lower blood pressure in the past month or reported high blood pressure (Canada), or having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during pregnancy (USA). Treatment was defined as taking medication to lower blood pressure, as recorded by the nurse (England), or a self-report of taking medication to lower blood pressure (Canada, USA). Treated and controlled was defined as taking medication to lower blood pressure and SBP $<140 \mathrm{mmHg}$ and $\mathrm{DBP}<90 \mathrm{mmHg}$; treated and uncontrolled a SBP $\geq 140 \mathrm{mmHg}$ or DBP $\geq 90 \mathrm{mmHg}$ while on medication to lower blood pressure. Aware, yet not treated, was defined by self-report and included having been diagnosed as hypertensive by a doctor or nurse (England) / health care provider (Canada, USA), and not taking medication to lower blood pressure.

Survey data were not age and sex standardized. They represent the current country-specific figures, and therefore correspond more precisely to each country's crude mortality rates for stroke and IHD. All prevalence figures are weighted using survey weights to represent each country's population. Standard errors were computed taking into account each country's sampling methodology. ${ }^{11-13}$ To be comparable across the three surveys, the analysis was restricted to individuals age 20-79 years and excluded pregnant women. The Canadian Health Measures Survey (CHMS) data analysis was performed using SAS® Enterprise Guide (Version 4.1, SAS Institute Inc., Cary, NC, 2006). The Health Survey for England (HSE) data analysis was performed using SPSS 19. The National Health and Nutrition Examination Survey (NHANES) data analysis was performed using SAS version 9.2 and SAS-Callable SUDAAN version 10 (RTI International)], to account for the complex sampling design.

The latest WHO country specific mortality data available were from 2008 for Canada and the USA ${ }^{14}$ and we used 2006 data for England. ${ }^{15}$ Crude mortality rates per 100,000 were obtained for men and women for stroke and ischemic heart disease (IHD) and plotted against country specific prevalence data for hypertension awareness, treatment, and control.

## Results

The distribution of SBP and DBP by sex, age, and country shows an increase in SBP with age and an increase, plateau and decrease of DBP with aging (Figure 1; Appendix 1 Table). SBP is higher in men than women in the younger age groups and becomes higher in women than men after age 60 years in Canada and age 70 years in England and USA. Mean SBP is overall higher in England than in the USA and Canada in all age-gender groups. DBP is similar in the 3 countries before age 50 and then falls more rapidly in the USA and is overall lower in men and women from the USA. The distribution of measured blood pressure (including treated individuals), by level, in Table 2 reflects the findings in Figure 1. Only 34\% of adults aged 20-79 years would be classified as having
a normal blood pressure ( $<120 / 80 \mathrm{mmHg}$ ) in England, compared with $50 \%$ in the USA and $66 \%$ in Canada. Pre-hypertension and stage 1 and 2 hypertension prevalence figures are also much higher in England than in the USA and Canada.

The prevalence of hypertension, and awareness, treatment, and control levels among those with hypertension are shown in Table 3. The prevalence of hypertension is lowest in Canada (19.5\%) and higher in the USA (29\%) and England (30\%). Hypertension awareness is close to $80 \%$ in both the USA (81\%) and Canada (83\%) and lower in England (65\%). England also has lower levels of hypertension treatment (England 51\%; USA 74\%; Canada 80\%) and control (England 27\%; USA $53 \%$; Canada $66 \%$ ). These patterns are similar in the different age and sex sub groups (Table 3). Among individuals treated for hypertension (i.e., taking medication to lower blood pressure), the proportion being controlled is lowest in England (53\%), while 71\% in the USA and 82\% in Canada are controlled.

The mean SBP and DBP are provided in Appendix 2 by the different prevalence categories of Table 3.The data are consistent with those in the previous tables showing the highest SBP mean in England in all categories. For DBP, England has also higher means than the USA and Canada among all hypertensives and aware and treated categories.

At the time when these surveys were conducted, Canada had the lowest stroke and IHD mortality rates while England had the highest. Rates of both outcomes were inversely related to the mean SBP in each country (Figure 2). We found a strong relationship between the selected blood pressure indicators and stroke and IHD mortality, the strongest relationship being between hypertension awareness and stroke mortality, especially in women (Figure 3). Stroke rates were higher in women than men for any level of each of the BP indicators and the opposite was true for IHD (Figure 2-3).

## Discussion

Although all 3 countries evaluated have had substantive improvement in most hypertension treatment indicators over the past two decades ${ }^{16-20}$, this study found marked differences in hypertension prevalence, awareness, treatment and control rates in England, the USA, and Canada. Canada has the lowest prevalence of hypertension at 19\% followed by England and United States at about $30 \%$ each. A previous study based on earlier cycles of these surveys also found little difference in the prevalence of hypertension between England and the USA. ${ }^{21}$ The main determinants of hypertension are known. These include poor dietary habits, excess sodium intake, physical inactivity, obesity, excess alcohol consumption, as well as age, gender, race and sociodemographic factors. The national differences in prevalence are likely related to differences in the interaction between these determinants as well as differences in the clinical systems, community programs, and environmental and policy supports for hypertension prevention and management. Compared to the USA, Canada has a lower rate of obesity but to our knowledge there has never been a comprehensive comparison of the determinants of blood pressure using appropriately adjusted data in these countries. A comprehensive comparison of the determinants of hypertension and the policies that fail to address adverse differences in the modifiable determinants would be an important next step.

Our study has also found important differences in the awareness, treatment and control of hypertension in the three countries. England, the USA, and Canada all have developed differing approaches to improve hypertension treatment and control. In the USA, several diverse approaches have been taken. $6,8,22$ Historically the USA has had one of the world's highest rates of hypertension awareness, treatment and control and has also seen improvements in these indicators with intensified efforts; ${ }^{18}$ however, despite broad clinical and community efforts, over half of adults with hypertension are uncontrolled based on current guidelines. ${ }^{19}$ Recent national activities and recommendations are staged to positively impact hypertension estimates. ${ }^{23-27}$

Importantly, we also found national-level differences in mortality rates from stroke and IHD, which paralleled the differences in hypertension awareness, treatment, and control between these 3 countries. Both stroke and IHD mortality were strongly inversely correlated with mean SBP in each country.

Efforts in England have included episodic national hypertension recommendations developed by the British Hypertension Society (B.H.S - a non-governmental organization of specialists and researchers) with the recommendations more recently being developed by a governmental organization in collaboration with the BHS. ${ }^{28}$ Implementation programs have included an extensive public program to educate people on the risks of salt for hypertension ${ }^{29}$ and also to an extensive government program to pay General Practitioners bonus payments for achieving benchmarks for hypertension care ${ }^{30}$ - although the efficacy of payment for performance for improving hypertension control has been questioned. ${ }^{31}$

In 2000, Canada launched an annually updated hypertension recommendations program (Canadian Hypertension Education Program (CHEP)). ${ }^{9}$ In 2006, the program was assisted by an extensive initiative to inform the public about hypertension and the health risks and opportunities to reduce dietary salt. ${ }^{32}$ The introduction of CHEP in Canada is temporally related to improvements in management patterns and has been also temporally associated with reduced CVD in Canada. ${ }^{33}$ It is difficult to assess how much the different national approaches to hypertension detection and management impact on the differences observed in our study. British Guidelines in place in $20066^{10,37}$ and since ${ }^{28}$ do not recommend the routine use of antihypertensive treatment for those with a systolic $\mathrm{BP}>140 \mathrm{mmHg}$ and/or diastolic $\mathrm{BP}>90 \mathrm{mmHg}$, rather only if such people have an estimated 10 year CV risk of $>20 \%$. Consequently treatment rates and control rates might be expected to be lower in England than in the USA \& Canada. Furthermore, in England, the National Institute for Health and Clinical Excellence's Quality and Outcomes Framework, which includes measures used in the calculation of provider reimbursement, included a higher blood pressure
target ( $<150 / 90$ ) during the period of data used for these analyses. This will be lowered (to $<140 / 90$ ) in 2013/2014 to align with national guidelines. In addition to the new National Institute for Health and Clinical Excellence (NICE) guidelines ${ }^{28}$, the national salt reduction program in England would be expected to result in further reductions in the prevalence of hypertension and improvement in hypertension treatment indicators in the recent and future years as Canadian and Finnish data suggest. ${ }^{34,35}$

There are several potential limitations to our current analyses. In addition to low response rates and hence small numbers in some strata, each country uses different methodology to assess blood pressure and relatively small differences in blood pressure can impact hypertension indicators. In particular Canada has adopted the use of a fully automated blood pressure device that operates in the absence of an observer and averages the last 5 of six blood pressure readings. The Canadian method reduces the influence of the observer (white coat effect) on blood pressure and results in a slightly lower average blood pressure than a single auscultatory blood pressure reading. Nevertheless using an algorithm to adjust the data in the Canadian survey to represent single manual reading results in little change in the major hypertension indicators as the difference in methods at the therapeutic cut point of $140 / 90 \mathrm{mmHg}$ is small. ${ }^{36}$ The close relationship between stroke mortality and hypertension prevalence and hypertension indicators suggest that blood pressure and hypertension differences seen in this study are real and biologically important. We did not use age- or gender-adjusted data from the different countries. The lack of adjustment was intended so that hypertension risk factors could be directly compared to stroke mortality for each country. In addition, in a separate analysis, comparison of age-adjusted data to a common standard population showed very little difference with the current figures. We were not able to obtain more recent common mortality data than 2008 for all countries. There is some overlap between the timing of the US and Canadian surveys, but the English survey was conducted more than one year earlier. Management of hypertension in England is likely to have improved since
2006. Increased blood pressure and hypertension represent major global threats to population health, with stroke and IHD being the most closely related adverse outcomes. ${ }^{4}$ Interventions to lower average population blood pressure and interventions to identify and control blood pressure in those with hypertension are critical to prevent blood pressure related complications. ${ }^{2-6}$ Nevertheless, hypertension control rates are low even in developed countries and most countries do not have formal programs to control hypertension. ${ }^{38}$ Further, population surveys indicate that approximately $29 \%$ of men and $25 \%$ of women have uncontrolled hypertension with increasing numbers of hypertension cases globally due to population growth and ageing. ${ }^{39}$ Hence, countries worldwide should consider introducing and evaluating coordinated programs to improve the prevention, detection, awareness, treatment, and control of hypertension, and our data suggest that the more assertive approach apparent in North America is associated with large benefits in terms of reduced cardiovascular mortality.

## References

1. WHO. World Health Organization, World Health Statistics 2012. World Health Organization, Geneva 2012 . Available at
http://www.who.int/gho/publications/world_health_statistics/2012/en/index.html. Accessed April 2013.
2. 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.
3. Gaziano TA, Bitton A, Anand S, Weinstein MC; International Society of Hypertension. The global cost of nonoptimal blood pressure. J Hypertens. 2009; 27: 1472-7.
4. Lewington S, Clarke R, Qizilbash N, Peto R, Collins R; Prospective Studies Collaboration. Agespecific 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.
5. Law MR, Morris JK, Wald NJ. Use of blood pressure lowering drugs in the prevention of cardiovascular disease: meta-analysis of 147 randomised trials in the context of expectations from prospective epidemiological studies. BMJ. 2009; 338: b1665.
6. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL Jr, 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.
7. Kearney PM, Whelton M, Reynolds K, Whelton PK, He J. Worldwide prevalence of hypertension: a systematic review. J Hypertens 2004; 22: 11-19
8. National Heart Lung and Blood Institute. National High Blood Pressure Education Program. Available at http://www.nhlbi.nih.gov/about/nhbpep/index.htm. Accessed April 2013.
9. McAlister FA. The Canadian Hypertension Education Program (CHEP)—a unique Canadian initiative. Can J Cardiol 2006; 22: 559-564.
10. National Institute for Health and Clinical Excellence. Hypertension: Clinical management of primary hypertension in adults. Clinical guidelines, CG127-Issued: August 2011. Available at http://guidance.nice.org.uk/CG127. Accessed April 2013.
11. CDC. National Health and Nutrition Examination Survey Data. Hyattsville, MD: US Department of Health and Human Services, CDC; 2010. Available at http://www.cdc.gov/nchs/nhanes/about_nhanes.htm. Accessed April 2013.
12. Craig R, Mindell J, eds. Health Survey for England 2006. London, United Kingdom: The Information Centre; 2008.
13. The Canadian Health Measures Survey: Rationale background and overview. Available at http://www.statcan.gc.ca/pub/82-003-s/82-003-s2007000-eng.htm. Accessed April 2013.
14. Causes of Death 2008 Summary Tables, May 2011. Health statistics and informatics Department, World Health Organization, Geneva, Switzerland. Available at http://www.who.int/evidence/bod. Accessed April 2013.
15. Mortality Statistics Newport: Office for National Statistics. Deaths registered in 2006. Review of the Registrar General on deaths in England and Wales, 2006.
http://www.ons.gov.uk/ons/rel/vsob1/mortality-statistics--deaths-registered-in-england-and-wales--series-dr-/2006/data-tables--2006.zip. Accessed April 2013.
16. Wilkins K, Campbell NRC, Joffres MR, McAlister FA, Nichol M, Quach S, et al. Blood pressure in Canadian adults. Health Reports. 2010: 21: 1-10.
17. Falaschetti E, Chaudhury M, Mindell J, Poulter NR. Continued Improvement In Hypertension Management In England: Results From The Health Survey For England 2006. Hypertension 2009; 53: 480-86.
18. Egan BM, Zhao Y, Axon RN. US trends in prevalence, awareness, treatment, and control of hypertension, 1988-2008. JAMA. 2010; 303: 2043-50.
19. Centers for Disease Control and Prevention (2012). Vital Signs: Awareness and treatment of uncontrolled hypertension among adults - United States, 2003-2010 Morbidity and Mortality Weekly Report; 61, 703-709.
20. McAlister FA, Wilkins K, Joffres M, Leenen FH, Fodor G, Gee M, et al. Changes in the rates of awareness, treatment and control of hypertension in Canada over the past two decades. CMAJ. 2011; 183: 1007-13.
21. Martinson ML, Teitler JO, Reichman NE. Health across the lifespan in the United States and England. Am J Epidemiol 2011; 173: 858-65.
22. United States Preventive Services Task Force. Recommendations. Available at http://www.uspreventiveservicestaskforce.org/recommendations.htm. Accessed April 2013.
23. Centers for Disease Control and Prevention (2011). Million Hearts: Strategies to reduce the prevalence of leading cardiovascular disease risk factors, United States, 2011. Morbidity and Mortality Weekly Report. 60; 1248-1251.
24. Centers for Disease Control and Prevention. Sodium Reduction in Communities Program. Available at http://www.cdc.gov/dhdsp/programs/sodium_reduction.htm. Accessed April 2013.
25. Centers for Disease Control and Prevention. Community Transformation Grant Program. Available at http://www.cdc.gov/communitytransformation/. Accessed April 2013.
26. U.S. Department of Health and Human Services, U.S. Department of Agriculture. Dietary Guidelines for Americans, 2010. 7th ed. Washington DC. 2011.
27. Institute of Medicine. A population-based policy and systems change approach to prevent and control hypertension. National Academy of Sciences. Washington DC. 2010.
28. National Institute for Health and Clinical Excellence. Hypertension: clinical management of primary hypertension in adults. Clinical guidelines, CG127. http://guidance.nice.org.uk/CG127. Accessed April 2013.
29. National Institute for Health and Clinical Excellence. Prevention of cardiovascular disease at the population level. Public health guidance, PH2; June 2010. Available at http://guidance.nice.org.uk/PH25. Accessed April 2013.
30. Doran T, Fullwood C, Gravelle H, Reeves D, Kontopantelis E, Hiroeh U, et al. Pay-forPerformance Programs in Family Practices in the United Kingdom. N Engl J Med 2006; 355: 375-384.
31. Serumaga B, Ross-Degnan D, Avery AJ, Elliott RA, Majumdar SR, Zhang F, et al. Effect of pay for performance on the management and outcomes of hypertension in the United Kingdom: interrupted time series study. BMJ. 2011; 342: d108
32. Campbell N, Young E, Drouin D, Legowski B, Adams MA, Farrell J, et al. A framework for discussion on how to improve prevention, management and control of hypertension in Canada. Can J Cardiol. 2012; 28: 262-69
33. McAlister FA, Feldman RD, Wyard K, Brant R, Campbell NR; CHEP Outcomes Research Task Force. The impact of the Canadian Hypertension Education Programme in its first decade. Eur Heart J. 2009; 30: 1434-9.
34. Joffres MR, Campbell NR, Manns B, Tu K. Estimate of the benefits of a population-based reduction in dietary sodium additives on hypertension and its related health care costs in Canada. Can J Cardiol. 2007; 23: 437-43.
35. Karppanen H, Mervaala E. Sodium intake and hypertension. Prog Cardiovasc Dis. 2006; 49: 5975.
36. Myers MG, McInnis NH, Fodor GJ, Leenen FH. Comparison between an automated and manual sphygmomanometer in a population survey. Am J Hypertens 2008; 21: 280-3.
37. National Institute for Health and Clinical Excellence. Hypertension: management of hypertension in adults in primary care. Clinical guidelines, CG34; June 2006. Available at www.nice.org.uk/nicemedia/pdf/CG034NICEguideline.pdf. Accessed April 2013.
38. Pereira M, Lunet N, Azevedo A, Barros H. Differences in prevalence, awareness, treatment and control of hypertension between developing and developed countries. J Hypertens. 2009; 27: 963-75.
39. Danaei G, Finucane MM, Lin JK, Singh GM, Paciorek CJ, Cowan MJ, et al. Global Burden of Metabolic Risk Factorsof Chronic Diseases Collaborating Group (Blood Pressure). National, regional, and global trends in systolic blood pressure since 1980: systematic analysis of health examination surveys and epidemiological studies with 786 country-years and $5 \cdot 4$ million participants. Lancet. 2011; 377: 568-77.

Table 1. Survey methods, by country.

| Country | Years of Survey | Sample <br> Frame | $n$ | Age Range | Response Rate |
| :---: | :---: | :---: | :---: | :---: | :---: |
| England | 2006 | Multistage, postal code address | 6,873 | 20-79 | 68\% household response rate, $88 \%$ individual response rate in co-operating households and $66 \%$ with nurse visit (examination response rate). |
| Canada | 2007-2009 | Multistage | 3,485 | 20-79 | Household response rate $=$ 70\% <br> Individual response rate to the household questionnaire $=$ 88\% Examination response rate $=85 \%$ |
| US | 2007-2010 | Multistage | 10,003 | 20-79 | Interview response rate $=79 \%$ Examination response rate $=$ 76\% <br> $93 \%$ of those examined had $\geq 2$ <br> blood pressure measurements |
| Country | Blood Pressure <br> Device | Technician | $N$ of Blood Pressure Measures | Study Protocol Used |  |
| England | Omron HEM 907 | Nurse | 3 | Mean o taken 1 | second and third measures minute apart after 5 minutes rest |
| Canada | $\begin{aligned} & \text { Bp TRUTM BP- } \\ & 300^{*} \end{aligned}$ | Health measures specialists | 6 | Average of last 5 of 6 measures taken one minute apart after a 5 minute rest period <br> Mean of second and third measurement taken 30 seconds apart after resting quietly in a sitting position for 5 minutes ${ }^{\dagger}$ |  |
| US | Calibrated $®$ VLok ${ }^{\circledR}$ cuff, Latex Inflation Bulb, Air-Flo® Control Valve. <br> Baumanometer® calibrated mercury wall model. | Physician | 3 |  |  |

[^0]
#### Abstract

All valid blood pressure readings excluding pregnant.


Figure 1. Distribution of Systolic and Diastolic Blood Pressure by Country, Age and Sex.


For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Table 2. Distribution of Measured Blood Pressure by Level, Sex, Age, and Country.

|  | Total | Normal |  | Pre- <br> Hypertension |  |  |  | Stage 1 |  | Stage 2 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | n | \% | se | n | \% | se | n | \% | se | n | \% | se |
| $\begin{gathered} \text { ENGLAND } \\ \text { All } \end{gathered}$ | 7,382 | 2,528 | 34.2 | 0.7 | 3,242 | 43.9 | 0.7 | 1235 | 16.7 | 0.5 | 376 | 5.1 | 0.3 |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Males | 3,555 | 761 | 21.4 | 0.8 | 1,903 | 53.5 | 0.9 | 709 | 19.9 | 0.7 | 182 | 5.1 | 0.4 |
| Females | 3,826 | 1,767 | 46.2 | 0.9 | 1,339 | 35 | 0.9 | 526 | 13.7 | 0.6 | 195 | 5.1 | 0.4 |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-39 | 2,618 | 1,273 | 48.6 | 1.2 | 1,115 | 42.6 | 1.1 | 210 | 8 | 0.6 | 20 | 0.8 | 0.2 |
| 40-59 | 2,962 | 966 | 32.6 | 0.9 | 1,360 | 45.9 | 0.9 | 482 | 16.3 | 0.7 | 155 | 5.2 | 0.4 |
| 60-79 | 1,801 | 289 | 16.1 | 1 | 767 | 42.6 | 1.5 | 543 | 30.2 | 1.3 | 201 | 11.2 | 0.9 |
| CANADA |  |  |  |  |  |  |  |  |  |  |  |  |  |
| All | 3,485 | 2,214 | 66.1 | 1.7 | 955 | 27.2 | 1.4 | 259 | 5.4 | 0.3 | 57 | $1.3{ }^{\text {E }}$ | $0.2{ }^{\text {E }}$ |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Males | 1,649 | 951 | 60.6 | 2.4 | 538 | 32.9 | 2.2 | 140 | 5.9 | 0.5 | 20 | 0.7E | $0.2{ }^{\text {E }}$ |
| Females | 1,836 | 1,263 | 71.6 | 1.4 | 417 | 21.6 | 1.1 | 119 | 4.8 | 0.6 | 37 | $2.0{ }^{\text {E }}$ | $0.5{ }^{\text {E }}$ |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-39 | 1,159 | 992 | 84.0 | 1.9 | 155 | 15.2 | 1.8 | F | F | F | F | F | F |
| 40-59 | 1,231 | 785 | 63.4 | 3.3 | 351 | 30.2 | 2.8 | 81 | 5.3 | 0.7 | 14 | $1.1{ }^{\text {E }}$ | $0.3{ }^{\text {E }}$ |
| 60-79 | 1,095 | 437 | 39.4 | 2.0 | 449 | 42.9 | 2.2 | 168 | 13.8 | 1.1 | 41 | 3.9E | $1.0^{\mathrm{E}}$ |
| USA |  |  |  |  |  |  |  |  |  |  |  |  |  |
| All | 10,003 | 4,663 | 50.3 | 0.8 | 3,615 | 36.0 | 0.7 | 1,296 | 11.0 | 0.4 | 429 | 2.7 | 0.2 |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Males | 5,033 | 1,998 | 42.2 | 1.0 | 2,109 | 42.7 | 1.0 | 713 | 12.2 | 0.6 | 213 | 2.8 | 0.3 |
| Females | 4,970 | 2,665 | 58.3 | 1.0 | 1,506 | 29.3 | 0.8 | 583 | 9.7 | 0.5 | 216 | 2.7 | 0.2 |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-39 | 3,394 | 2,210 | 65.2 | 1.1 | 1,007 | 29.7 | 1.1 | 148 | 4.4 | 0.4 | 29 | 0.7 | 0.1 |
| 40-59 | 3,586 | 1,608 | 46.5 | 1.3 | 1,371 | 39.1 | 1.1 | 473 | 11.9 | 0.7 | 134 | 2.6 | 0.3 |
| 60-79 | 3,023 | 845 | 30.8 | 1.3 | 1,237 | 41.3 | 1.2 | 675 | 21.2 | 1.1 | 266 | 6.7 | 0.5 |

${ }^{\text {E }}$ Interpret with caution (coefficient of variation $16.6 \%$ to $33.3 \%$ )
${ }^{\mathrm{F}}$ Too unreliable to be reported (coefficient of variation greater than 33.3\%)
Normal: Systolic $<120$ and diastolic $<80$. Pre-Hypertension: $120 \leq$ Systolic $<140$ or $80 \leq$ diastolic $<90$. Stage 1 :
$140 \leq$ Systolic $<160$ or $90 \leq$ diastolic $<100$. Stage 2 : Systolic $\geq 160$ or diastolic $\geq 100$. Regardless of medication use

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml ${ }^{19}$

Table 3. Hypertension Prevalence and Percentage with Hypertension, Aware, Treated, Controlled, by sex, age group, and country.

|  | Prevalence |  | Aware |  | Treated |  | Treated \& Controlled |  | Treated \& not controlled |  | Aware, not treated |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | \% | SE | \% | SE | \% | SE | \% | SE | \% | SE | \% | SE |
| $\begin{aligned} & \text { ENGLAND } \\ & \text { All } \end{aligned}$ | 30.0 | 0.7 | 65.3 | 1.2 | 51.3 | 1.2 | 27.3 | 1.1 | 23.9 | 0.9 | 14.1 | 0.8 |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |
| Male | 32.9 | 0.9 | 60.6 | 1.5 | 45.1 | 1.6 | 23.9 | 1.4 | 21.2 | 1.2 | 15.5 | 1.1 |
| Female | 27.3 | 0.8 | 70.7 | 1.5 | 58.2 | 1.6 | 31.1 | 1.6 | 27 | 1.4 | 12.5 | 1.1 |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-39 | 9.3 | 0.7 | 35 | 3.1 | 10.6 | 2.1 | 5 | 1.4 | 5.6 | 1.7 | 24.4 | 2.9 |
| 40-59 | 27.9 | 0.8 | 59.3 | 1.7 | 40.8 | 1.8 | 23.1 | 1.5 | 17.7 | 1.2 | 18.5 | 1.3 |
| 60-80 | 63.7 | 1.3 | 76.1 | 1.6 | 67.4 | 1.7 | 35.1 | 1.8 | 32.3 | 1.6 | 8.7 | 0.9 |
| CANADA |  |  |  |  |  |  |  |  |  |  |  |  |
| All | 19.5 | 0.6 | 83.4 | 1.8 | 79.9 | 2.0 | 65.8 | 2.0 | 14.0 | 2.0 | $3.5{ }^{\text {E }}$ | $0.9{ }^{\text {E }}$ |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |
| Male | 19.7 | 1.1 | 80.4 | 2.2 | 76.5 | 2.1 | 66.8 | 3.0 | 9.7 E | $2.0{ }^{\text {E }}$ | 3.9E | 0.9 E |
| Female | 19.3 | 0.6 | 86.5 | 2.0 | 83.3 | 2.4 | 64.9 | 2.8 | $18.4{ }^{\text {E }}$ | $3.2{ }^{\text {E }}$ | F | F |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| 40-59 | 18.4 | 1.5 | 80.4 | 2.7 | 73.4 | 3.7 | 65.4 | 3.8 | $8.0{ }^{\text {E }}$ | $1.8{ }^{\text {E }}$ | $7.0{ }^{\text {E }}$ | $2.3{ }^{\text {E }}$ |
| 60-79 | 53.2 | 2.4 | 86.7 | 1.8 | 85.7 | 2.1 | 66.8 | 1.8 | 19.0 | 2.6 | F | F |
| USA |  |  |  |  |  |  |  |  |  |  |  |  |
| All | 29.1 | 0.8 | 81.1 | 1.0 | 74.0 | 1.1 | 52.8 | 1.0 | 21.2 | 0.7 | 7.0 | 0.7 |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |
| Male | 29.4 | 1 | 77.7 | 1.4 | 69.1 | 1.5 | 48.7 | 1.6 | 20.3 | 1.1 | 8.6 | 1 |
| Female | 28.8 | 0.9 | 84.6 | 1.2 | 79.1 | 1.4 | 57 | 1.5 | 22.1 | 1 | 5.5 | 0.7 |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-39 | 7.7 | 0.6 | 61.1 | 4.6 | 47.2 | 4.0 | 35.0 | 3.6 | 12.2 | 2.4 | 13.9 | 2.5 |
| 40-59 | 31.1 | 1.2 | 82.4 | 1.4 | 73.1 | 1.8 | 53.5 | 1.7 | 19.6 | 1.3 | 9.4 | 1.0 |
| 60-79 | 63.6 | 1.3 | 84.2 | 1.3 | 80.9 | 1.4 | 56.1 | 1.5 | 24.8 | 0.9 | 3.3 | 0.6 |

${ }^{\text {E }}$ Interpret with caution (coefficient of variation $16.6 \%$ to $33.3 \%$ )
${ }^{\mathrm{F}}$ Too unreliable to be reported (coefficient of variation greater than 33.3\%)
Hypertension: Systolic pressure $\geq 140$ or diastolic pressure $\geq 90$ or currently taking blood pressure lowering medication

Awareness, treatment and control were assessed among those with hypertension.
Aware: Self-report of having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during pregnancy (ENGLAND); Self-reported BP medication use in the past month or self-reported high blood pressure (Canada); Self-report of having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during pregnancy (USA)
Treated: Taking medication to lower blood pressure recorded by the nurse (ENGLAND);Taking medication to lower blood pressure, self-report (Canada, USA);
Treated and controlled: Taking medication to lower blood pressure and DBP $<90 \mathrm{~mm} \mathrm{Hg}$ and $\mathrm{SBP}<140 \mathrm{~mm} \mathrm{Hg}$ Treated and uncontrolled: Taking medication to lower blood pressure and DBP $>=90 \mathrm{~mm} \mathrm{Hg}$ or SBP $>=140 \mathrm{~mm} \mathrm{Hg}$ Aware, not treated: Self-reported of having been diagnosed as hypertensive by a doctor or nurse, no taking medication to lower blood pressure (ENGLAND); Self-reported of having been told by health care provider that they have high blood pressure, not taking medication to lower blood pressure (Canada);Self-reported of having been told by health care provider that they have high blood pressure, not taking medication to lower blood pressure (USA)
Unaware: No self report of having been diagnosed as hypertensive by a doctor or nurse (ENGLAND); No self report of having been told that they have high blood pressure and no self report of BP medication use in the past month (Canada); No self report of having been told that they have high blood pressure (USA)

Figure 2. Stroke and Ischemic Heart Disease (IHD) Mortality* by Country Mean SBP

*2008 mortality rate per 100,000 (WHO) for USA and Canada; 2006 Statistics for England and Wales.

Figure 3. Stroke and IHD mortality by Country Prevalence of Hypertension Awareness, Treatment and Control

*2008 mortality rate per 100,000 (WHO) for USA and Canada; 2006 Statistics for England and Wales.

Appendix 1. Distribution of Systolic and Diastolic Blood Pressure by Sex, Age, and Country.

| England |  |  |  |  |  | CANADA |  |  |  |  | USA |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | n | SBP | se | DBP | se | n | SBP | se | DBP | se | n | SBP | se | DBP | se |
| Males |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-24 | 153 | 126.7 | 0.8 | 69.2 | 0.8 | 127 | 106.6 | 0.7 | 67.5 | 0.8 | 436 | 117.0 | 0.6 | 66.3 | 0.9 |
| 25-29 | 196 | 127.9 | 0.8 | 72.5 | 0.8 | 98 | 108.9 | 1.0 | 70.1 | 0.8 | 413 | 118.6 | 0.8 | 68.9 | 0.6 |
| 30-34 | 275 | 127.5 | 0.7 | 73.5 | 0.6 | 134 | 112.2 | 0.9 | 73.8 | 0.7 | 410 | 118.4 | 0.6 | 71.6 | 0.5 |
| 35-39 | 320 | 126.8 | 0.7 | 74.1 | 0.6 | 165 | 112.1 | 0.8 | 74.7 | 0.6 | 468 | 120.3 | 0.6 | 74.7 | 0.6 |
| 40-44 | 389 | 126.5 | 0.6 | 75.7 | 0.5 | 190 | 113.5 | 0.8 | 76.5 | 0.6 | 442 | 120.7 | 0.8 | 76.1 | 0.7 |
| 45-49 | 335 | 130.9 | 0.9 | 79.5 | 0.7 | 173 | 115.9 | 0.9 | 77.7 | 0.6 | 448 | 121.8 | 0.9 | 75.9 | 0.8 |
| 50-54 | 316 | 132.2 | 0.9 | 78.4 | 0.6 | 134 | 117.9 | 1.0 | 78.8 | 0.6 | 510 | 124.4 | 0.9 | 75.9 | 0.7 |
| 55-59 | 384 | 134.6 | 0.8 | 78.6 | 0.6 | 85 | 120.6 | 1.6 | 77.4 | 0.9 | 383 | 125.1 | 0.9 | 75.2 | 0.7 |
| 60-64 | 326 | 137.0 | 0.9 | 77.5 | 0.6 | 201 | 120.5 | 1.0 | 76.2 | 0.6 | 517 | 128.3 | 1.0 | 72.4 | 0.9 |
| 65-69 | 141 | 138.2 | 2.1 | 76.1 | 1.1 | 141 | 122.7 | 1.3 | 73.6 | 0.7 | 381 | 127.0 | 1.4 | 67.9 | 1.1 |
| 70-74 | 124 | 137.3 | 1.7 | 72.1 | 1.0 | 107 | 125.2 | 1.6 | 72.8 | 1.0 | 345 | 130.0 | 1.3 | 67.1 | 0.7 |
| 75-79 | 84 | 138.9 | 1.9 | 71.9 | 1.1 | 94 | 123.2 | 1.6 | 70.3 | 0.9 | 280 | 132.3 | 1.6 | 66.0 | 1.0 |
| All males | 3,043 | 131.1 | 0.3 | 75.3 | 0.2 | 1649 | 115.1 | 0.3 | 74.5 | 0.2 | 5033 | 122.4 | 0.3 | 72.3 | 0.4 |
| Females |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-24 | 215 | 112.2 | 0.6 | 67.4 | 0.5 | 100 | 101.7 | 0.9 | 66.6 | 0.8 | 423 | 108.6 | 0.6 | 64.4 | 0.6 |
| 25-29 | 252 | 112.9 | 0.6 | 69.2 | 0.6 | 142 | 98.2 | 0.7 | 63.9 | 0.7 | 388 | 109.7 | 0.5 | 66.3 | 0.7 |
| 30-34 | 348 | 113.0 | 0.6 | 70.6 | 0.5 | 172 | 103.3 | 0.8 | 69.0 | 0.6 | 404 | 109.5 | 0.7 | 67.6 | 0.7 |
| 35-39 | 462 | 115.4 | 0.6 | 72.3 | 0.5 | 221 | 103.4 | 0.8 | 69.6 | 0.6 | 452 | 112.0 | 0.7 | 71.0 | 0.5 |
| 40-44 | 492 | 118.9 | 0.7 | 74.2 | 0.5 | 192 | 105.6 | 0.8 | 69.6 | 0.6 | 488 | 113.1 | 0.8 | 70.5 | 0.7 |
| 45-49 | 414 | 123.1 | 0.9 | 76.0 | 0.6 | 204 | 111.5 | 1.0 | 73.0 | 0.7 | 486 | 117.3 | 1.0 | 71.9 | 0.8 |
| 50-54 | 383 | 125.6 | 1.0 | 76.3 | 0.6 | 133 | 115.3 | 1.2 | 73.2 | 0.7 | 452 | 120.0 | 0.7 | 72.4 | 0.6 |
| 55-59 | 451 | 129.1 | 0.9 | 75.9 | 0.5 | 120 | 114.7 | 1.4 | 71.3 | 0.8 | 377 | 124.5 | 1.3 | 71.5 | 0.8 |
| 60-64 | 403 | 131.9 | 0.9 | 75.3 | 0.5 | 193 | 123.0 | 1.3 | 72.4 | 0.6 | 536 | 127.3 | 1.0 | 70.1 | 0.8 |
| 65-69 | 183 | 135.7 | 1.4 | 73.9 | 0.8 | 146 | 129.3 | 1.5 | 73.9 | 0.8 | 343 | 128.9 | 1.5 | 66.4 | 1.2 |
| 70-74 | 121 | 140.3 | 1.8 | 73.4 | 0.8 | 114 | 125.8 | 1.4 | 69.3 | 0.9 | 365 | 134.0 | 1.2 | 64.7 | 0.8 |
| 75-79 | 106 | 144.1 | 2.0 | 71.3 | 1.1 | 99 | 134.2 | 2.2 | 70.0 | 1.0 | 256 | 135.7 | 1.2 | 61.8 | 1.2 |
| All <br> females | 3,830 | 123.7 | 0.4 | 73.1 | 0.2 | 1836 | 111.4 | 0.4 | 70.2 | 0.2 | 4970 | 118.1 | 0.4 | 69.0 | 0.4 |

Appendix 2. Mean Systolic (SBP) and Diastolic (DBP) Blood Pressure (mm Hg) among Hypertensive Individuals, by Awareness, Treatment and Control, and by Country.

|  |  | ENGLAND |  | CANADA |  | USA |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | SBP | DBP | SBP | DBP | SBP | DBP |
| Non hypertensive | mean | 119.9 | 71.2 | 109.3 | 71.1 | 114.8 | 69.3 |
|  | se | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 | 0.4 |
| All, Hypertensive | mean | 144.3 | 81.0 | 129.5 | 77.3 | 133.7 | 74.0 |
|  | se | 0.5 | 0.3 | 0.6 | 0.4 | 0.4 | 0.5 |
| All, Aware | mean | 141.7 | 78.5 | 126.1 | 75.2 | 130.8 | 72.3 |
|  | se | 0.6 | 0.4 | 0.6 | 0.4 | 0.4 | 0.5 |
| All, Treated | mean | 138.8 | 75.9 | 125.2 | 74.4 | 129.0 | 71.1 |
|  | se | 0.7 | 0.4 | 0.6 | 0.4 | 0.4 | 0.5 |
| Treated and Controlled | mean | 125.4 | 71.2 | 119.7 | 72.8 | 120.2 | 68.3 |
|  | se | 0.5 | 0.4 | 0.5 | 0.4 | 0.3 | 0.5 |
| Treated and not controlled | mean | 154.1 | 81.2 | 151.1 | 81.9 | 151.0 | 78.0 |
|  | se | 0.8 | 0.6 | 1.3 | 0.9 | 0.6 | 0.7 |
| Aware, not treated | mean | 151.5 | 88.1 | $147.2{ }^{\text {E }}$ | $93.8{ }^{\text {E }}$ | 149.3 | 85.1 |
|  | se | 0.8 | 0.6 | $2.5{ }^{\text {E }}$ | $2.0{ }^{\text {E }}$ | 1.2 | 1.1 |
| Unaware | mean | 149.3 | 85.5 | 146.7 | 87.6 | 146.1 | 81.5 |
|  | se | 0.5 | 0.5 | 1.0 | 0.7 | 0.6 | 1.3 |

${ }^{\text {E }}$ Interpret with caution (coefficient of variation $16.6 \%$ to $33.3 \%$ )
Hypertension: Systolic pressure $\geq 140$ or diastolic pressure $\geq 90$ or currently taking blood pressure lowering medication Aware: Self-report of having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during pregnancy (England); Self-reported blood pressure medication use in the past month or self-reported high blood pressure (Canada); Self-report of having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during pregnancy (USA)

Treated: Taking medication to lower blood pressure recorded by the nurse (England);Taking medication to lower blood pressure, self-report (Canada, USA);
Treated and controlled: Taking medication to lower blood pressure and DBP $<90 \mathrm{~mm} \mathrm{Hg}$ and SBP $<140 \mathrm{~mm} \mathrm{Hg}$
Treated and uncontrolled: Taking medication to lower blood pressure and DBP $>=90 \mathrm{~mm} \mathrm{Hg}$ or SBP $>=140 \mathrm{~mm} \mathrm{Hg}$ Aware, not treated: Self-reported of having been diagnosed as hypertensive by a doctor or nurse, no taking medication to lower blood pressure (England); Self-reported of having been told by health care provider that they have high blood pressure, not taking medication to lower blood pressure (Canada);Self-reported of having been told by health care provider that they have high blood pressure, not taking medication to lower blood pressure (USA)
Unaware: No self report of having been diagnosed as hypertensive by a doctor or nurse (England); No self report of having been told that they have high blood pressure and no self report of blood pressure medication use in the past month (Canada); No self report of having been told that they have high blood pressure (USA)

## STROBE Statement-Checklist of items that should be included in reports of cross-sectional studies Item <br> No <br> Recommendation

Title and abstract $1 \quad$ (a) Indicate the study's design with a commonly used term in the title or the abstract Done 'National Surveys'
(b) Provide in the abstract an informative and balanced summary of what was done and what was found

Done

| Introduction |  |  |
| :--- | :--- | :--- |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported <br> Done |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses <br> Done |
| Methods | 4 | Present key elements of study design early in the paper <br> Done |
| Study design | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, <br> exposure, follow-up, and data collection <br> Done |
| Setting |  |  |


| Participants | 6 | (a) Give the eligibility criteria, and the sources and methods of selection of participants <br> Done -Brief description- |
| :--- | :---: | :--- |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect <br> modifiers. Give diagnostic criteria, if applicable <br> Done when relevant. |
| Data sources/ <br> measurement | $8^{*}$ | For each variable of interest, give sources of data and details of methods of assessment <br> (measurement). Describe comparability of assessment methods if there is more than <br> one group <br> Done |
| Bias | 9 | Describe any efforts to address potential sources of bias <br> Not applicable Limitations covered later |
| Study size | 10 | Explain how the study size was arrived at <br> Referred to survey methodology papers |
| Quantitative |  |  |
| variables | Explain how quantitative variables were handled in the analyses. If applicable, describe <br> which groupings were chosen and why <br> Done |  |
| Statistical methods | 12 | (a) |
| Done- Confounding not considered in this type of analysis |  |  |

(b) Describe any methods used to examine subgroups and interactions
Not applicable
(c) Explain how missing data were addressed
Not applicable
(d) $\quad$ If applicable,
describe analytical methods taking account of sampling strategy
(e) Describe any sensitivity analyses

| Results |  |  |
| :---: | :---: | :---: |
| Participants | 13* | (a) Report numbers of individuals at each stage of study-eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed <br> Numbers provided in tables |
|  |  | (b) <br> Give reasons for <br> non-participation at each stage <br> Not relevant for this study. Provided in the original survey method papers |
|  |  | (c) <br> Consider use of a flow diagram |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders <br> Not relevant for this study. Provided in the original survey method papers |
|  |  | (b) Indicate number of participants with missing data for each variable of interest Numbers provided in tables |
| Outcome data | 15* | Report numbers of outcome events or summary measures Numbers provided in tables |
| Main results | 16 | (a) <br> Give unadjusted <br> estimates and, if applicable, confounder-adjusted estimates and their precision (eg, $95 \%$ confidence interval). Make clear which confounders were adjusted for and why they were included <br> Not applicable |
|  |  | (b) Report category <br> boundaries when continuous variables were categorized <br> Standard error provided to simplify tables. Would be too cumbersome to add all CI |
|  |  | (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period |
| Other analyses | 17 | Report other analyses done-eg analyses of subgroups and interactions, and sensitivity analyses <br> Not applicable |
| Discussion |  |  |
| Key results | 18 | Summarise key results with reference to study objectives <br> Done |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias <br> Done |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence Done |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results <br> Done-Since these are national representative populations surveys |
| Other information |  |  |


| Funding $22 \quad$Give the source of funding and the role of the funders for the present study and, if <br> applicable, for the original study on which the present article is based <br> Done |
| :--- | :--- |

## Hypertension Prevalence, Awareness, Treatment, and Control in National Surveys from England, the USA, and Canada, and Correlation with Stroke and Ischemic Heart Disease Mortality

| Journal: | BMJ Open |
| ---: | :--- |
| Manuscript ID: | bmjopen-2013-003423.R1 |
| Article Type: | Research |
| Date Submitted by the Author: | 26-Jul-2013 |
| Complete List of Authors: | Joffres, Michel; Simon Fraser University, Faculty of Health Sciences <br> Falaschetti, Emanuela; School of Public Health, Imperial College London, <br> Imperial Clinical Trial Unit <br> Gillespie, Cathleen; Centers for Disease Control and Prevention, Division <br> for Heart Disease and Stroke Prevention <br> Robitaille, Cynthia; Public Health Agency of Canada, Centre for Chronic <br> Disease Prevention <br> Loustalot, Fleetwood; Centers for Disease Control and Prevention, Division <br> for Heart Disease and Stroke Prevention <br> Poulter, Neil; Imperial College London, International Centre for Circulatory <br> Health <br> Mcalister, Finlay; University of Alberta Canada, Medicine <br> Johansen, Helen; University of Ottawa, <br> Baclic, Oliver; Public Health Agency of Canada, <br> Campbell, Norm; University of Calgary, Libin Cardiovascular Institute of <br> Alberta |
| <b>Primary Subject |  |
| Heading</b>: | Public health |
| Secondary Subject Heading: | Cardiovascular medicine, Epidemiology, Health policy |
| Keywords: | Hypertension < CARDIOLOGY, Stroke < NEUROLOGY, Myocardial infarction <br> < CARDIOLOGY, EPIDEMIOLOGY, PUBLIC HEALTH |

SCHOLARONE
Manuscripts
Manuscripts

# Hypertension Prevalence, Awareness, Treatment, and Control in National Surveys from England, the USA, and Canada, and Correlation with Stroke and Ischemic Heart Disease Mortality 

Michel Joffres, professor of epidemiology ${ }^{1}$, Emanuela Falaschetti, research fellow in clinical trial statistics ${ }^{2}$, Cathleen Gillespie, senior statistician ${ }^{3}$, Cynthia Robitaille, epidemiologist ${ }^{4}$, Fleetwood Loustalot, epidemiologist ${ }^{3}$, Neil Poulter, professor ${ }^{5}$, Finlay A. McAlister, professor ${ }^{6}$, Helen Johansen, adjunct professor ${ }^{7}$, Oliver Baclic, medical advisor ${ }^{8}$, Norm Campbell, professor ${ }^{9}$
${ }^{1}$ Faculty of Health Sciences, Simon Fraser University, Burnaby, BC V5A 1S6, Canada.
${ }^{2}$ Imperial Clinical Trial Unit, School of Public Health, Imperial College London, St Mary’s Campus, Norfolk Place, W2 1PG London UK
${ }^{3}$ Division for Heart Disease and Stroke Prevention, Centers for Disease Control and Prevention, 4770 Buford Hwy NE, Mailstop F-72, Atlanta GA 30341
${ }^{4}$ Centre for Chronic Disease Prevention, Public Health Agency of Canada 785 Carling Avenue, A.L. 6806A, Ottawa, Ontario, Canada, K1A 0K9
${ }^{5}$ International Centre for Circulatory Health, Imperial College London, 59-61 North Wharf Road, London W2 1PG, UK
${ }^{6}$ Division of General Internal Medicine, University of Alberta Hospital 8440112 Street, Edmonton, Alberta T6G 2R7, Canada
${ }^{7}$ Department of Community Medicine and Epidemiology, University of Ottawa, Epidemiology \& Community Medicine, Room 3105, 451 Smyth Road, Ottawa, Ontario, Canada, K1H 8M5
${ }^{8}$ Public Health Agency of Canada, 130 Colonnade Rd, Ottawa, K1A0K9
${ }^{9}$ Departments of Medicine, Community Health Sciences and of Physiology and Pharmacology, Libin Cardiovascular Institute, University of Calgary, Canada Libin Cardiovascular Institute of Alberta, University of Calgary, 3280 Hospital Drive NW, Calgary Alberta, T2N 4Z6

Correspondance to: Michel Joffres mjoffres@sfu.ca

The Corresponding Author has the right to grant on behalf of all authors and does grant on behalf of all authors, an exclusive licence (or non exclusive for government employees) on a worldwide basis to the BMJ Publishing Group Ltd to permit this article (if accepted) to be published in BMJ editions and any other BMJPGL products and sublicences such use and exploit all subsidiary rights, as set out in our licence.

Competing Interests. All authors have completed the Unified Competing Interest form atwww.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; Dr. Poulter reports grants from Pfizer, grants from Hypertension Trust and personal fees from various Pharma companies, other from Servier, outside the submitted work; Dr Norm Campbell receives for salary support for a HSFC CIHR Chair in Hypertension Prevention and Control; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval was not required for these secondary analyses since all the original studies had their own ethical approval process.

Details of funding - No specific funding was provided for this study. Funding for NHANES comes from two primary sources: direct funding through the NCHS base budget and reimbursable funding from collaborating agencies; The Health Survey for England was funded by the National Health Centre; Health Canada and the Public Health Agency of Canada supported Statistics Canada in obtaining federal funding for for the Canadian Health Measures Survey. Other sources of support: FAM is supported by an Alberta Innovates Health Solutions Senior Health Scholar Award and the University of Alberta/Capital Health Chair in Cardiovascular Outcomes Research. NC holds the Heart and Stroke Foundation of Canada CIHR Chair in Hypertension Prevention and Control. NP is grateful for support from the NIHR Biomedical Research funding scheme and the NIHR Senior Investigator Award. Funding of the original surveys;

Statement of independence of researchers from funders - The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention, the Public Health Agency of Canada or the UK Department of Health.

Data sharing statement. All the authors had access to the original tables from the different studies. There is no additional data available.

Author's Contributions: Michel Joffres, Emanuela Falaschetti , Cathleen Gillespie, Cynthia Robitaille contributed to the data analysis, interpretation and writing.
Fleetwood Loustalot, Neil Poulter, Finlay A. McAlister, Helen Johansen, Oliver Baclic, and Norm Campbell contributed to the data interpretation and writing.

## Article Summary

1) Article focus

- Comparison of hypertension prevalence, awareness, treatment, and control in 3 National studies, England, USA, and Canada
- Correlation with stroke and ischemic heart disease mortality

2) Key messages

- Important variation by country
- Strong relationship between hypertension indicators and stroke mortality
- Gaps in the management of hypertension

3) Strengths and limitations

- Strengths
- National population data
- Detailed data on hypertension characteristics
- Strong correlation with meaningful outcome, mortality
- Limitations
- Data from England from 2006, but provide an important basis for measuring progress (current data not yet available)
- Limited to 3 countries
- Ecological correlation with mortality that excludes looking at confounders


#### Abstract

Objective Comparison of recent national survey data on prevalence, awareness, treatment and control of hypertension in England, the USA and Canada, and correlation of these parameters with each country stroke and ischemic heart disease (IHD) mortality.


Methods Non-instutionalized population surveys from England (2006), the USA (2007-2010) and Canada (2007-2009) using standardized protocols and devices. Analysis included individuals age 20-79 years. Stroke and IHD mortality rates were plotted against countries' specific prevalence data.

Results Mean systolic blood pressure (SBP) was higher in England than in the USA and Canada in all age-gender groups. Mean diastolic blood pressure (DBP) was similar in the three countries before age 50 and then fell more rapidly in the USA and was the lowest in the USA. Only $34 \%$ had a BP under 140/90 mmHg in England, compared with 50\% in the USA and 66\% in Canada. Prehypertension and stage 1 and 2 hypertension prevalence figures were the highest in England. Hypertension prevalence ( $\geq 140 \mathrm{mmHg}$ SBP and/or $\geq 90 \mathrm{mmHg}$ DBP) was lower in Canada (19.5\%) than in the USA (29\%) and England (30\%). Hypertension awareness was higher in both the USA (81\%) and Canada (83\%), than in England (65\%). England also had lower levels of hypertension treatment (51\%; USA 74\%; Canada 80\%) and control (< 140/90 mmHg; 27\%; USA 53\%; Canada 66\%). Canada had the lowest Stroke and IHD mortality rates, England the highest, and rates were inversely related to the mean SBP in each country and strongly related to blood pressure indicators, the strongest relationship being between low hypertension awareness and stroke mortality.

Conclusion While current prevention efforts in England should result in future improved figures, especially at younger ages, these data still show important gaps in the management of hypertension in these countries, with consequences on stroke and IHD mortality.

## Introduction

Increased blood pressure is the leading risk factor for premature death, stroke, and heart disease worldwide. ${ }^{1}$ In the year 2000, the world was estimated to have close to 1 billion people with hypertension and predicted an increase to 1.56 billion by 2025.2 ${ }^{2}$ The global economic burden of increased blood pressure was estimated to consume 370 billion US \$ worldwide and $10 \%$ of health care expenditures. ${ }^{3}$ Usual blood pressure is strongly and directly related to vascular and overall mortality without evidence of a threshold down to at least $115 / 75 \mathrm{mmHg}^{4}$ with small changes in blood pressure resulting in substantial changes in vascular disease. ${ }^{5}$

Based on clinical and population research, increased blood pressure, hypertension and hypertension related complications are largely preventable. Lifestyle changes can lower blood pressure and prevent hypertension while antihypertensive drug therapy can effectively reduce the cardiovascular events attributed to hypertension. ${ }^{1-6}$ Nevertheless, most people with hypertension worldwide are not effectively treated and controlled to recommended blood pressure targets. ${ }^{7}$ There are few national programs to serve as models for prevention and control of hypertension and few countries have embarked on national hypertension prevention and control programs. The United States (USA) blood pressure education program was established in $1972{ }^{8}$, while Canada (2000) and England (2004) have more recent initiatives. ${ }^{9,10}$ This manuscript compares recent data on prevalence, awareness, treatment and control of hypertension in England, the USA and Canada and correlates these hypertension-related parameters in the three countries to mortality from stroke and ischemic heart disease (IHD).

## Methods

Survey methods used in England, the USA, and Canada are summarized in Table 1. Detailed methodology for each survey is available elsewhere. ${ }^{11-13}$ Briefly, each survey is a representative sample of each country's non-institutionalized population and uses standardized protocols and
devices. While the England (2006) and Canada (2007-2009) surveys used automatic oscillometric devices, the USA (2007-2010) survey used mercury wall sphygmomanometer models. The number of blood pressure measurements available for analysis varied by count of blood pressure measures and survey protocols (Table 1).

In these analyses, hypertension was defined as a mean systolic blood pressure (SBP) $\geq 140 \mathrm{mmHg}$ or a mean diastolic blood pressure (DBP) $\geq 90 \mathrm{mmHg}$ or a respondent self-report of medication to lower blood pressure. Pre-hypertension (SBP 120-139 mmHg or DBP 80-89 mmHg), stage 1 (SBP $140-159 \mathrm{mmHg}$ or DBP $90-99 \mathrm{mmHg}$ ), and stage 2 (SBP $\geq 160 \mathrm{mmHg}$ or DBP $\geq 100 \mathrm{mmHg}$ ) hypertension were defined according to the Seventh Report of the Joint National Committee on the Prevention, Detection, Evaluation and Treatment of High Blood Pressure (JNC 7) definitions. ${ }^{6}$ Prevalence, awareness, treatment, control and awareness of hypertension were defined using commonly recognized standards. Prevalence was defined as SBP $\geq 140$ or DBP $\geq 90$ or currently taking medication to lower their blood pressure. Awareness was defined by self-report and included having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during pregnancy (England), medication to lower blood pressure in the past month or reported high blood pressure (Canada), or having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during pregnancy (USA). Treatment was defined as taking medication to lower blood pressure, as recorded by the nurse (England), or a self-report of taking medication to lower blood pressure (Canada, USA). Treated and controlled was defined as taking medication to lower blood pressure and SBP $<140 \mathrm{mmHg}$ and $\mathrm{DBP}<90 \mathrm{mmHg}$; treated and uncontrolled a SBP $\geq 140 \mathrm{mmHg}$ or DBP $\geq 90 \mathrm{mmHg}$ while on medication to lower blood pressure. Aware, yet not treated, was defined by self-report and included having been diagnosed as hypertensive by a doctor or nurse (England) / health care provider (Canada, USA), and not taking medication to lower blood pressure.

Survey data were not age and sex standardized. They represent the current country-specific figures, and therefore correspond more precisely to each country's crude mortality rates for stroke and IHD. All prevalence figures are weighted using survey weights to represent each country's population. Standard errors were computed taking into account each country's sampling methodology. ${ }^{11-13}$ To be comparable across the three surveys, the analysis was restricted to individuals age 20-79 years and excluded pregnant women. The Canadian Health Measures Survey (CHMS) data analysis was performed using SAS® Enterprise Guide (Version 4.1, SAS Institute Inc., Cary, NC, 2006). The Health Survey for England (HSE) data analysis was performed using SPSS 19. The National Health and Nutrition Examination Survey (NHANES) data analysis was performed using SAS version 9.2 and SAS-Callable SUDAAN version 10 (RTI International)], to account for the complex sampling design.

The latest WHO country specific mortality data available were from 2008 for Canada and the USA ${ }^{14}$ and we used 2006 data for England. ${ }^{15}$ Crude mortality rates per 100,000 were obtained for men and women for stroke and ischemic heart disease (IHD) and plotted against country specific prevalence data for hypertension awareness, treatment, and control.

## Results

The distribution of SBP and DBP by sex, age, and country shows an increase in SBP with age and an increase, plateau and decrease of DBP with aging (Figure 1; Appendix 1 Table). SBP is higher in men than women in the younger age groups and becomes higher in women than men after age 60 years in Canada and age 70 years in England and USA. Mean SBP is overall higher in England than in the USA and Canada in all age-gender groups. DBP is similar in the 3 countries before age 50 and then falls more rapidly in the USA and is overall lower in men and women from the USA. The distribution of measured blood pressure (including treated individuals), by level, in Table 2 reflects the findings in Figure 1. Only 34\% of adults aged 20-79 years would be classified as having
a normal blood pressure ( $<120 / 80 \mathrm{mmHg}$ ) in England, compared with 50\% in the USA and $66 \%$ in Canada. Pre-hypertension and stage 1 and 2 hypertension prevalence figures are also much higher in England than in the USA and Canada.

The prevalence of hypertension, and awareness, treatment, and control levels among those with hypertension are shown in Table 3. The prevalence of hypertension is lowest in Canada (19.5\%) and higher in the USA (29\%) and England (30\%). Hypertension awareness is close to $80 \%$ in both the USA (81\%) and Canada (83\%) and lower in England (65\%). England also has lower levels of hypertension treatment (England 51\%; USA 74\%; Canada 80\%) and control (England 27\%; USA $53 \%$; Canada $66 \%$ ). These patterns are similar in the different age and sex sub groups (Table 3). Among individuals treated for hypertension (i.e., taking medication to lower blood pressure), the proportion being controlled is lowest in England (53\%), while 71\% in the USA and 82\% in Canada are controlled.

The mean SBP and DBP are provided in Appendix 2 by the different prevalence categories of Table 3. The data are consistent with those in the previous tables showing the highest SBP mean in England in all categories. For DBP, England has also higher means than the USA and Canada among all hypertensives and aware and treated categories.

At the time when these surveys were conducted, Canada had the lowest stroke and IHD mortality rates while England had the highest. Rates of both outcomes were inversely related to the mean SBP in each country (Figure 2). We found a strong relationship between the selected blood pressure indicators and stroke and IHD mortality, the strongest relationship being between hypertension awareness and stroke mortality, especially in women (Figure 3). Stroke rates were higher in women than men for any level of each of the BP indicators and the opposite was true for IHD (Figure 2-3).

## Discussion

Although all 3 countries evaluated have had substantive improvement in most hypertension treatment indicators over the past two decades ${ }^{16-20}$, this study found marked differences in hypertension prevalence, awareness, treatment and control rates in England, the USA, and Canada. Canada has the lowest prevalence of hypertension at 19\% followed by England and United States at about $30 \%$ each. A previous study based on earlier cycles of these surveys also found little difference in the prevalence of hypertension between England and the USA. ${ }^{21}$ The main determinants of hypertension are known. These include poor dietary habits, excess sodium intake, physical inactivity, obesity, excess alcohol consumption, as well as age, gender, race and sociodemographic factors. The national differences in prevalence are likely related to differences in the interaction between these determinants as well as differences in the clinical systems, community programs, and environmental and policy supports for hypertension prevention and management. Compared to the USA, Canada has a lower rate of obesity but to our knowledge there has never been a comprehensive comparison of the determinants of blood pressure using appropriately adjusted data in these countries. A comprehensive comparison of the determinants of hypertension and the policies that fail to address adverse differences in the modifiable determinants would be an important next step. This is also important since these data show an important difference in the younger age groups between England, Canada and the USA. Since blood pressure tracks with age ${ }^{22}$, efforts to influence the determinants of hypertension are essential to reduce hypertension prevalence in the older age groups. The recent decrease in childhood obesity in England ${ }^{23}$ should be followed by a reduction in blood pressure in the next surveys. Our study has also found important differences in the awareness, treatment and control of hypertension in the three countries. England, the USA, and Canada all have developed differing approaches to improve hypertension treatment and control. In the USA, several diverse approaches have been taken. $6,8,24$ Historically the USA has had one of the world's highest rates of hypertension awareness, treatment and control and has also seen improvements in these indicators
with intensified efforts; ${ }^{18}$ however, despite broad clinical and community efforts, over half of adults with hypertension are uncontrolled based on current guidelines. ${ }^{19}$ Recent national activities and recommendations are staged to positively impact hypertension estimates. 25-29

Importantly, we also found national-level differences in mortality rates from stroke and IHD, which paralleled the differences in hypertension awareness, treatment, and control between these 3 countries. Both stroke and IHD mortality were strongly inversely correlated with mean SBP in each country.

Efforts in England have included episodic national hypertension recommendations developed by the British Hypertension Society (B.H.S - a non-governmental organization of specialists and researchers) with the recommendations more recently being developed by a governmental organization in collaboration with the BHS. ${ }^{30}$ Implementation programs have included an extensive public program to educate people on the risks of salt for hypertension ${ }^{31}$ and also to an extensive government program to pay General Practitioners bonus payments for achieving benchmarks for hypertension care ${ }^{32}$ - although the efficacy of payment for performance for improving hypertension control has been questioned. ${ }^{33}$

In 2000, Canada launched an annually updated hypertension recommendations program (Canadian Hypertension Education Program (CHEP)). ${ }^{9}$ In 2006, the program was assisted by an extensive initiative to inform the public about hypertension and the health risks and opportunities to reduce dietary salt. ${ }^{34}$ The introduction of CHEP in Canada is temporally related to improvements in management patterns and has been also temporally associated with reduced CVD in Canada. ${ }^{35}$ It is difficult to assess how much the different national approaches to hypertension detection and management impact on the differences observed in our study. British Guidelines in place in $2006^{10,39}$ and since ${ }^{30}$ do not recommend the routine use of antihypertensive treatment for those with a systolic BP >140 mmHg and/or diastolic BP $>90 \mathrm{mmHg}$, rather only if such people have an estimated 10 year CV risk of $>20 \%$. Consequently treatment rates and control rates might be
expected to be lower in England than in the USA \& Canada. Furthermore, in England, the National Institute for Health and Clinical Excellence's Quality and Outcomes Framework, which includes measures used in the calculation of provider reimbursement, included a higher blood pressure target ( $<150 / 90$ ) during the period of data used for these analyses. This will be lowered (to $<140 / 90$ ) in 2013/2014 to align with national guidelines. In addition to the new National Institute for Health and Clinical Excellence (NICE) guidelines ${ }^{30}$, the national salt reduction program in England would be expected to result in further reductions in the prevalence of hypertension and improvement in hypertension treatment indicators in the recent and future years as Canadian and Finnish data suggest. ${ }^{36,37}$

There are several potential limitations to our current analyses. In addition to low response rates and hence small numbers in some strata, each country uses different methodology to assess blood pressure and relatively small differences in blood pressure can impact hypertension indicators. In particular Canada has adopted the use of a fully automated blood pressure device that operates in the absence of an observer and averages the last 5 of six blood pressure readings. The Canadian method reduces the influence of the observer (white coat effect) on blood pressure and results in a slightly lower average blood pressure than a single auscultatory blood pressure reading. Nevertheless using an algorithm to adjust the data in the Canadian survey ${ }^{38}$ to represent single manual reading results in little change in the major hypertension indicators as the difference in methods at the therapeutic cut point of $140 / 90 \mathrm{mmHg}$ is relatively small, but might reduce the differences between the US and Canada. The close relationship between stroke mortality and hypertension prevalence and hypertension indicators suggest that blood pressure and hypertension differences seen in this study are real and biologically important. We acknowledge the limitation of using three points for our mortality graphs, which require a high level of correlation to be statistically significant.

We did not use age- or gender-adjusted data from the different countries. The lack of adjustment was intended so that hypertension risk factors could be directly compared to stroke mortality for each country. In addition, in a separate analysis, comparison of age-adjusted data to a common standard population showed very little difference with the current figures. We were not able to obtain more recent common mortality data than 2008 for all countries. There is some overlap between the timing of the US and Canadian surveys, but the English survey was conducted more than one year earlier. Management of hypertension in England is likely to have improved since 2006. Increased blood pressure and hypertension represent major global threats to population health, with stroke and IHD being the most closely related adverse outcomes. ${ }^{4}$ Interventions to lower average population blood pressure and interventions to identify and control blood pressure in those with hypertension are critical to prevent blood pressure related complications. ${ }^{2-6}$ Nevertheless, hypertension control rates are low even in developed countries and most countries do not have formal programs to control hypertension. ${ }^{40}$ Further, population surveys indicate that approximately $29 \%$ of men and $25 \%$ of women have uncontrolled hypertension with increasing numbers of hypertension cases globally due to population growth and ageing. ${ }^{41}$ Hence, countries worldwide should consider introducing and evaluating coordinated programs to improve the prevention, detection, awareness, treatment, and control of hypertension, and our data suggest that the more assertive approach apparent in North America is associated with large benefits in terms of reduced cardiovascular mortality. A greater focus on prevention of high blood pressure in the younger age groups is also necessary.

## References

1. WHO. World Health Organization, World Health Statistics 2012. World Health Organization, Geneva 2012 . Available at
http://www.who.int/gho/publications/world_health_statistics/2012/en/index.html. Accessed April 2013.
2. Kearney PM, Whelton M, Reynolds K, et al. Global burden of hypertension: analysis of worldwide data. Lancet. 2005; 365: 217-23.
3. Gaziano TA, Bitton A, Anand S, et al; International Society of Hypertension. The global cost of nonoptimal blood pressure. J Hypertens. 2009; 27: 1472-7.
4. Lewington S, Clarke R, Qizilbash N, et al; 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.
5. Law MR, Morris JK, Wald NJ. Use of blood pressure lowering drugs in the prevention of cardiovascular disease: meta-analysis of 147 randomised trials in the context of expectations from prospective epidemiological studies. BMJ. 2009; 338: b1665.
6. 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.
7. Kearney PM, Whelton M, Reynolds K, et al. Worldwide prevalence of hypertension: a systematic review. J Hypertens 2004; 22: 11-19
8. National Heart Lung and Blood Institute. National High Blood Pressure Education Program. Available at http://www.nhlbi.nih.gov/about/nhbpep/index.htm. Accessed April 2013.
9. McAlister FA. The Canadian Hypertension Education Program (CHEP)-a unique Canadian initiative. Can J Cardiol 2006; 22: 559-564.
10. National Institute for Health and Clinical Excellence. Hypertension: Clinical management of primary hypertension in adults. Clinical guidelines, CG127-Issued: August 2011. Available at http://guidance.nice.org.uk/CG127. Accessed April 2013.
11. CDC. National Health and Nutrition Examination Survey Data. Hyattsville, MD: US Department of Health and Human Services, CDC; 2010. Available at http://www.cdc.gov/nchs/nhanes/about_nhanes.htm. Accessed April 2013.
12. Craig R, Mindell J, eds. Health Survey for England 2006. London, United Kingdom: The Information Centre; 2008.
13. The Canadian Health Measures Survey: Rationale background and overview. Available at http://www.statcan.gc.ca/pub/82-003-s/82-003-s2007000-eng.htm. Accessed April 2013.
14. Causes of Death 2008 Summary Tables, May 2011. Health statistics and informatics Department, World Health Organization, Geneva, Switzerland. Available at http://www.who.int/evidence/bod. Accessed April 2013.
15. Mortality Statistics Newport: Office for National Statistics. Deaths registered in 2006. Review of the Registrar General on deaths in England and Wales, 2006.
http://www.ons.gov.uk/ons/rel/vsob1/mortality-statistics--deaths-registered-in-england-and-wales--series-dr-/2006/data-tables--2006.zip. Accessed April 2013.
16. Wilkins K, Campbell NRC, Joffres MR, et al. Blood pressure in Canadian adults. Health Reports. 2010: 21: 1-10.
17. Falaschetti E, Chaudhury M, Mindell J, et al. Continued Improvement In Hypertension Management In England: Results From The Health Survey For England 2006. Hypertension 2009; 53: 480-86.
18. Egan BM, Zhao Y, Axon RN. US trends in prevalence, awareness, treatment, and control of hypertension, 1988-2008. JAMA. 2010; 303: 2043-50.
19. Centers for Disease Control and Prevention (2012). Vital Signs: Awareness and treatment of uncontrolled hypertension among adults - United States, 2003-2010 Morbidity and Mortality Weekly Report; 61, 703-709.
20. McAlister FA, Wilkins K, Joffres M, et al. Changes in the rates of awareness, treatment and control of hypertension in Canada over the past two decades. CMAJ. 2011; 183: 1007-13.
21. Martinson ML, Teitler JO, Reichman NE. Health across the lifespan in the United States and England. Am J Epidemiol 2011; 173: 858-65.
22. Cheng S, Xanthakis V, Sullivan LM, et al. Blood pressure tracking over the adult life course: patterns and correlates in the Framingham heart study. Hypertension. 2012; 60: 1393-9.
23. Lien N, Henriksen HB, Nymoen LL, et al. Availability of data assessing the prevalence and trends of overweight and obesity among European adolescents. Public Health Nutr. 2010; 13: 1680-7.
24. United States Preventive Services Task Force. Recommendations. Available at http://www.uspreventiveservicestaskforce.org/recommendations.htm. Accessed April 2013.
25. Centers for Disease Control and Prevention (2011). Million Hearts: Strategies to reduce the prevalence of leading cardiovascular disease risk factors, United States, 2011. Morbidity and Mortality Weekly Report. 60; 1248-1251.
26. Centers for Disease Control and Prevention. Sodium Reduction in Communities Program. Available at http://www.cdc.gov/dhdsp/programs/sodium_reduction.htm. Accessed April 2013.
27. Centers for Disease Control and Prevention. Community Transformation Grant Program. Available at http://www.cdc.gov/communitytransformation/. Accessed April 2013.
28. U.S. Department of Health and Human Services, U.S. Department of Agriculture. Dietary Guidelines for Americans, 2010. 7th ed. Washington DC. 2011.
29. Institute of Medicine. A population-based policy and systems change approach to prevent and control hypertension. National Academy of Sciences. Washington DC. 2010.
30. National Institute for Health and Clinical Excellence. Hypertension: clinical management of primary hypertension in adults. Clinical guidelines, CG127. http://guidance.nice.org.uk/CG127. Accessed April 2013.
31. National Institute for Health and Clinical Excellence. Prevention of cardiovascular disease at the population level. Public health guidance, PH2; June 2010. Available at http://guidance.nice.org.uk/PH25. Accessed April 2013.
32. Doran T, Fullwood C, Gravelle H, et al. Pay-for-Performance Programs in Family Practices in the United Kingdom. N Engl J Med 2006; 355: 375-384.
33. Serumaga B, Ross-Degnan D, Avery AJ, et al. Effect of pay for performance on the management and outcomes of hypertension in the United Kingdom: interrupted time series study. BMJ. 2011; 342: d108
34. Campbell N, Young E, Drouin D, et al. A framework for discussion on how to improve prevention, management and control of hypertension in Canada. Can J Cardiol. 2012; 28: 26269
35. McAlister FA, Feldman RD, Wyard K, et al; CHEP Outcomes Research Task Force. The impact of the Canadian Hypertension Education Programme in its first decade. Eur Heart J. 2009; 30: 1434-9.
36. Joffres MR, Campbell NR, Manns B, et al. Estimate of the benefits of a population-based reduction in dietary sodium additives on hypertension and its related health care costs in Canada. Can J Cardiol. 2007; 23: 437-43.
37. Karppanen H, Mervaala E. Sodium intake and hypertension. Prog Cardiovasc Dis. 2006; 49: 5975.
38. Myers MG, McInnis NH, Fodor GJ, et al. Comparison between an automated and manual sphygmomanometer in a population survey. Am J Hypertens 2008; 21: 280-3.
39. National Institute for Health and Clinical Excellence. Hypertension: management of hypertension in adults in primary care. Clinical guidelines, CG34; June 2006. Available at www.nice.org.uk/nicemedia/pdf/CG034NICEguideline.pdf. Accessed April 2013.
40. Pereira M, Lunet N, Azevedo A, et al. Differences in prevalence, awareness, treatment and control of hypertension between developing and developed countries. J Hypertens. 2009; 27: 963-75.
41. Danaei G, Finucane MM, Lin JK, et al. Global Burden of Metabolic Risk Factorsof Chronic Diseases Collaborating Group (Blood Pressure). National, regional, and global trends in systolic
blood pressure since 1980: systematic analysis of health examination surveys and epidemiological studies with 786 country-years and $5 \cdot 4$ million participants. Lancet. 2011; 377: 568-77.

Figure 1. Distribution of Systolic and Diastolic Blood Pressure by Country, Age and Sex.

Figure 2. Stroke and Ischemic Heart Disease (IHD) Mortality* by Country Mean SBP
*2008 mortality rate per 100,000 (WHO) for USA and Canada; 2006 Statistics for England and Wales.

Figure 3. Stroke and IHD mortality by Country Prevalence of Hypertension Awareness, Treatment and Control
*2008 mortality rate per 100,000 (WHO) for USA and Canada; 2006 Statistics for England and Wales

Table 1. Survey methods, by country.

| Country | Years of Survey | Sampling | $n$ | Age Range | Response Rate |
| :---: | :---: | :---: | :---: | :---: | :---: |
| England | 2006 | Multistage | 6,873 | 20-79 | 68\% household response rate, 88\% individual response rate in co-operating households and $66 \%$ with nurse visit (examination response rate). |
| Canada | 2007-2009 | Multistage | 3,485 | 20-79 | Household response rate $=$ 70\% <br> Individual response rate to the household questionnaire $=$ 88\% Examination response rate $=85 \%$ |
| US | 2007-2010 | Multistage | 10,003 | 20-79 | Interview response rate $=79 \%$ <br> Examination response rate $=$ 76\% <br> $93 \%$ of those examined had $\geq 2$ <br> blood pressure measurements |
| Country | Blood Pressure Device | Technician | N of Blood Pressure Measures | Study Protocol Used |  |
| England | Omron HEM 907 | Nurse | 3 | Mean of second and third measures taken 1 minute apart after 5 minutes rest |  |
| Canada | Bp TRUTM ${ }^{\text {™ }}$ 300* | Health measures specialists | 6 | Average of last 5 of 6 measures taken one minute apart after a 5 minute rest period <br> Mean of second and third measurement taken 30 seconds apart after resting quietly in a sitting position for 5 minutes ${ }^{\dagger}$ |  |
| US | Calibrated ${ }^{\circledR}$ VLok ${ }^{\circledR}$ cuff, Latex Inflation Bulb, Air-Flo® Control Valve. <br> Baumanometer® calibrated mercury wall model. | Physician | 3 |  |  |

[^1]Table 2. Distribution of Measured Blood Pressure by Level, Sex, Age, and Country.

|  | Total | Normal |  | Pre- <br> Hypertension |  |  |  | Stage 1 |  | Stage 2 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | n | \% | se | n | \% | se | n | \% | se | n | \% | se |
| $\begin{gathered} \text { ENGLAND } \\ \text { All } \end{gathered}$ | 7,382 | 2,528 | 34.2 | 0.7 | 3,242 | 43.9 | 0.7 | 1235 | 16.7 | 0.5 | 376 | 5.1 | 0.3 |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Males | 3,555 | 761 | 21.4 | 0.8 | 1,903 | 53.5 | 0.9 | 709 | 19.9 | 0.7 | 182 | 5.1 | 0.4 |
| Females | 3,826 | 1,767 | 46.2 | 0.9 | 1,339 | 35 | 0.9 | 526 | 13.7 | 0.6 | 195 | 5.1 | 0.4 |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-39 | 2,618 | 1,273 | 48.6 | 1.2 | 1,115 | 42.6 | 1.1 | 210 | 8 | 0.6 | 20 | 0.8 | 0.2 |
| 40-59 | 2,962 | 966 | 32.6 | 0.9 | 1,360 | 45.9 | 0.9 | 482 | 16.3 | 0.7 | 155 | 5.2 | 0.4 |
| 60-79 | 1,801 | 289 | 16.1 | 1 | 767 | 42.6 | 1.5 | 543 | 30.2 | 1.3 | 201 | 11.2 | 0.9 |
| CANADA |  |  |  |  |  |  |  |  |  |  |  |  |  |
| All | 3,485 | 2,214 | 66.1 | 1.7 | 955 | 27.2 | 1.4 | 259 | 5.4 | 0.3 | 57 | $1.3{ }^{\text {E }}$ | $0.2{ }^{\text {E }}$ |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Males | 1,649 | 951 | 60.6 | 2.4 | 538 | 32.9 | 2.2 | 140 | 5.9 | 0.5 | 20 | 0.7E | $0.2{ }^{\text {E }}$ |
| Females | 1,836 | 1,263 | 71.6 | 1.4 | 417 | 21.6 | 1.1 | 119 | 4.8 | 0.6 | 37 | $2.0{ }^{\text {E }}$ | $0.5{ }^{\text {E }}$ |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-39 | 1,159 | 992 | 84.0 | 1.9 | 155 | 15.2 | 1.8 | F | F | F | F | F | F |
| 40-59 | 1,231 | 785 | 63.4 | 3.3 | 351 | 30.2 | 2.8 | 81 | 5.3 | 0.7 | 14 | $1.1{ }^{\text {E }}$ | $0.3{ }^{\text {E }}$ |
| 60-79 | 1,095 | 437 | 39.4 | 2.0 | 449 | 42.9 | 2.2 | 168 | 13.8 | 1.1 | 41 | 3.9E | $1.0^{\mathrm{E}}$ |
| USA |  |  |  |  |  |  |  |  |  |  |  |  |  |
| All | 10,003 | 4,663 | 50.3 | 0.8 | 3,615 | 36.0 | 0.7 | 1,296 | 11.0 | 0.4 | 429 | 2.7 | 0.2 |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Males | 5,033 | 1,998 | 42.2 | 1.0 | 2,109 | 42.7 | 1.0 | 713 | 12.2 | 0.6 | 213 | 2.8 | 0.3 |
| Females | 4,970 | 2,665 | 58.3 | 1.0 | 1,506 | 29.3 | 0.8 | 583 | 9.7 | 0.5 | 216 | 2.7 | 0.2 |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-39 | 3,394 | 2,210 | 65.2 | 1.1 | 1,007 | 29.7 | 1.1 | 148 | 4.4 | 0.4 | 29 | 0.7 | 0.1 |
| 40-59 | 3,586 | 1,608 | 46.5 | 1.3 | 1,371 | 39.1 | 1.1 | 473 | 11.9 | 0.7 | 134 | 2.6 | 0.3 |
| 60-79 | 3,023 | 845 | 30.8 | 1.3 | 1,237 | 41.3 | 1.2 | 675 | 21.2 | 1.1 | 266 | 6.7 | 0.5 |

${ }^{\text {E }}$ Interpret with caution (coefficient of variation $16.6 \%$ to $33.3 \%$ )
${ }^{\mathrm{F}}$ Too unreliable to be reported (coefficient of variation greater than 33.3\%)
Normal: Systolic $<120$ and diastolic $<80$. Pre-Hypertension: $120 \leq$ Systolic $<140$ or $80 \leq$ diastolic $<90$. Stage 1 : $140 \leq$ Systolic $<160$ or $90 \leq$ diastolic $<100$. Stage 2: Systolic $\geq 160$ or diastolic $\geq 100$. Regardless of medication use

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtm²

## Page 23 of 61

Table 3. Hypertension Prevalence and Percentage with Hypertension, Aware, Treated, Controlled, by sex, age group, and country.

|  | Prevalence |  | Aware |  | Treated |  | Treated \& Controlled |  | Treated \& not controlled |  | Aware, not treated |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | \% | SE | \% | SE | \% | SE | \% | SE | \% | SE | \% | SE |
| ENGLAND <br> All | 30.0 | 0.7 | 65.3 | 1.2 | 51.3 | 1.2 | 27.3 | 1.1 | 23.9 | 0.9 | 14.1 | 0.8 |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |
| Male | 32.9 | 0.9 | 60.6 | 1.5 | 45.1 | 1.6 | 23.9 | 1.4 | 21.2 | 1.2 | 15.5 | 1.1 |
| Female | 27.3 | 0.8 | 70.7 | 1.5 | 58.2 | 1.6 | 31.1 | 1.6 | 27 | 1.4 | 12.5 | 1.1 |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-39 | 9.3 | 0.7 | 35 | 3.1 | 10.6 | 2.1 | 5 | 1.4 | 5.6 | 1.7 | 24.4 | 2.9 |
| 40-59 | 27.9 | 0.8 | 59.3 | 1.7 | 40.8 | 1.8 | 23.1 | 1.5 | 17.7 | 1.2 | 18.5 | 1.3 |
| 60-80 | 63.7 | 1.3 | 76.1 | 1.6 | 67.4 | 1.7 | 35.1 | 1.8 | 32.3 | 1.6 | 8.7 | 0.9 |
| CANADA |  |  |  |  |  |  |  |  |  |  |  |  |
| All | 19.5 | 0.6 | 83.4 | 1.8 | 79.9 | 2.0 | 65.8 | 2.0 | 14.0 | 2.0 | $3.5{ }^{\text {E }}$ | $0.9{ }^{\text {E }}$ |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |
| Male | 19.7 | 1.1 | 80.4 | 2.2 | 76.5 | 2.1 | 66.8 | 3.0 | $9.7{ }^{\text {E }}$ | $2.0{ }^{\text {E }}$ | 3.9E | 0.9 E |
| Female | 19.3 | 0.6 | 86.5 | 2.0 | 83.3 | 2.4 | 64.9 | 2.8 | $18.4{ }^{\text {E }}$ | $3.2{ }^{\text {E }}$ | F | F |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |
| $20-39$ | $2.0{ }^{\text {E }}$ | $0.6{ }^{\text {E }}$ | 64.4 | 9.8 | $58.4{ }^{\text {E }}$ | $10.3{ }^{\text {E }}$ | $56.8{ }^{\text {E }}$ | $10.6{ }^{\text {E }}$ | F | F | F | F |
| 40-59 | 18.4 | 1.5 | 80.4 | 2.7 | 73.4 | 3.7 | 65.4 | 3.8 | $8.0{ }^{\text {E }}$ | $1.8{ }^{\text {E }}$ | $7.0^{\text {E }}$ | $2.3{ }^{\text {E }}$ |
| 60-79 | 53.2 | 2.4 | 86.7 | 1.8 | 85.7 | 2.1 | 66.8 | 1.8 | 19.0 | 2.6 | F | F |
| USA |  |  |  |  |  |  |  |  |  |  |  |  |
| All | 29.1 | 0.8 | 81.1 | 1.0 | 74.0 | 1.1 | 52.8 | 1.0 | 21.2 | 0.7 | 7.0 | 0.7 |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |
| Male | 29.4 | 1 | 77.7 | 1.4 | 69.1 | 1.5 | 48.7 | 1.6 | 20.3 | 1.1 | 8.6 | 1 |
| Female | 28.8 | 0.9 | 84.6 | 1.2 | 79.1 | 1.4 | 57 | 1.5 | 22.1 | 1 | 5.5 | 0.7 |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-39 | 7.7 | 0.6 | 61.1 | 4.6 | 47.2 | 4.0 | 35.0 | 3.6 | 12.2 | 2.4 | 13.9 | 2.5 |
| 40-59 | 31.1 | 1.2 | 82.4 | 1.4 | 73.1 | 1.8 | 53.5 | 1.7 | 19.6 | 1.3 | 9.4 | 1.0 |
| 60-79 | 63.6 | 1.3 | 84.2 | 1.3 | 80.9 | 1.4 | 56.1 | 1.5 | 24.8 | 0.9 | 3.3 | 0.6 |

${ }^{\mathrm{E}}$ Interpret with caution (coefficient of variation $16.6 \%$ to $33.3 \%$ )
${ }^{\text {F }}$ Too unreliable to be reported (coefficient of variation greater than 33.3\%)
Hypertension: Systolic pressure $\geq 140$ or diastolic pressure $\geq 90$ or currently taking blood pressure lowering medication Awareness, treatment and control were assessed among those with hypertension.

Aware: Self-report of having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during pregnancy (ENGLAND); Self-reported BP medication use in the past month or self-reported high blood pressure (Canada); Self-report of having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during pregnancy (USA)
Treated: Taking medication to lower blood pressure recorded by the nurse (ENGLAND);Taking medication to lower blood pressure, self-report (Canada, USA);
Treated and controlled: Taking medication to lower blood pressure and DBP $<90 \mathrm{~mm} \mathrm{Hg}$ and SBP $<140 \mathrm{~mm} \mathrm{Hg}$ Treated and uncontrolled: Taking medication to lower blood pressure and DBP >=90 mm Hg or SBP >=140 mm Hg Aware, not treated: Self-reported of having been diagnosed as hypertensive by a doctor or nurse, not taking medication to lower blood pressure (ENGLAND); Self-reported of having been told by health care provider that they have high blood pressure, not taking medication to lower blood pressure (Canada);Self-reported of having been told by health care provider that they have high blood pressure, not taking medication to lower blood pressure (USA)
Unaware: No self report of having been diagnosed as hypertensive by a doctor or nurse (ENGLAND); No self report of having been told that they have high blood pressure and no self report of BP medication use in the past month (Canada); No self report of having been told that they have high blood pressure (USA)



Figure 1. Distribution of Systolic and Diastolic Blood Pressure by Country, Age and Sex. $119 \times 155 \mathrm{~mm}(300 \times 300$ DPI)



Figure 2. Stroke and Ischemic Heart Disease (IHD) Mortality* by Country Mean SBP $119 \times 57 \mathrm{~mm}$ ( $300 \times 300$ DPI)


Figure 3. Stroke and IHD mortality by Country Prevalence of Hypertension Awareness, Treatment and Control
$119 \times 73 \mathrm{~mm}$ ( $300 \times 300$ DPI)

Appendix 1. Mean Systolic and Diastolic Blood Pressure by Sex, Age, and Country.

|  | England |  |  |  |  | CANADA |  |  |  |  | USA |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | n | SBP | se | DBP | se | n | SBP | se | DBP | se | n | SBP | se | DBP | se |
| Males |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-24 | 153 | 126.7 | 0.8 | 69.2 | 0.8 | 127 | 106.6 | 0.7 | 67.5 | 0.8 | 436 | 117.0 | 0.6 | 66.3 | 0.9 |
| 25-29 | 196 | 127.9 | 0.8 | 72.5 | 0.8 | 98 | 108.9 | 1.0 | 70.1 | 0.8 | 413 | 118.6 | 0.8 | 68.9 | 0.6 |
| 30-34 | 275 | 127.5 | 0.7 | 73.5 | 0.6 | 134 | 112.2 | 0.9 | 73.8 | 0.7 | 410 | 118.4 | 0.6 | 71.6 | 0.5 |
| 35-39 | 320 | 126.8 | 0.7 | 74.1 | 0.6 | 165 | 112.1 | 0.8 | 74.7 | 0.6 | 468 | 120.3 | 0.6 | 74.7 | 0.6 |
| 40-44 | 389 | 126.5 | 0.6 | 75.7 | 0.5 | 190 | 113.5 | 0.8 | 76.5 | 0.6 | 442 | 120.7 | 0.8 | 76.1 | 0.7 |
| 45-49 | 335 | 130.9 | 0.9 | 79.5 | 0.7 | 173 | 115.9 | 0.9 | 77.7 | 0.6 | 448 | 121.8 | 0.9 | 75.9 | 0.8 |
| 50-54 | 316 | 132.2 | 0.9 | 78.4 | 0.6 | 134 | 117.9 | 1.0 | 78.8 | 0.6 | 510 | 124.4 | 0.9 | 75.9 | 0.7 |
| 55-59 | 384 | 134.6 | 0.8 | 78.6 | 0.6 | 85 | 120.6 | 1.6 | 77.4 | 0.9 | 383 | 125.1 | 0.9 | 75.2 | 0.7 |
| 60-64 | 326 | 137.0 | 0.9 | 77.5 | 0.6 | 201 | 120.5 | 1.0 | 76.2 | 0.6 | 517 | 128.3 | 1.0 | 72.4 | 0.9 |
| 65-69 | 141 | 138.2 | 2.1 | 76.1 | 1.1 | 141 | 122.7 | 1.3 | 73.6 | 0.7 | 381 | 127.0 | 1.4 | 67.9 | 1.1 |
| 70-74 | 124 | 137.3 | 1.7 | 72.1 | 1.0 | 107 | 125.2 | 1.6 | 72.8 | 1.0 | 345 | 130.0 | 1.3 | 67.1 | 0.7 |
| 75-79 | 84 | 138.9 | 1.9 | 71.9 | 1.1 | 94 | 123.2 | 1.6 | 70.3 | 0.9 | 280 | 132.3 | 1.6 | 66.0 | 1.0 |
| All males | 3,043 | 131.1 | 0.3 | 75.3 | 0.2 | 1649 | 115.1 | 0.3 | 74.5 | 0.2 | 5033 | 122.4 | 0.3 | 72.3 | 0.4 |
| Females |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-24 | 215 | 112.2 | 0.6 | 67.4 | 0.5 | 100 | 101.7 | 0.9 | 66.6 | 0.8 | 423 | 108.6 | 0.6 | 64.4 | 0.6 |
| 25-29 | 252 | 112.9 | 0.6 | 69.2 | 0.6 | 142 | 98.2 | 0.7 | 63.9 | 0.7 | 388 | 109.7 | 0.5 | 66.3 | 0.7 |
| 30-34 | 348 | 113.0 | 0.6 | 70.6 | 0.5 | 172 | 103.3 | 0.8 | 69.0 | 0.6 | 404 | 109.5 | 0.7 | 67.6 | 0.7 |
| 35-39 | 462 | 115.4 | 0.6 | 72.3 | 0.5 | 221 | 103.4 | 0.8 | 69.6 | 0.6 | 452 | 112.0 | 0.7 | 71.0 | 0.5 |
| 40-44 | 492 | 118.9 | 0.7 | 74.2 | 0.5 | 192 | 105.6 | 0.8 | 69.6 | 0.6 | 488 | 113.1 | 0.8 | 70.5 | 0.7 |
| 45-49 | 414 | 123.1 | 0.9 | 76.0 | 0.6 | 204 | 111.5 | 1.0 | 73.0 | 0.7 | 486 | 117.3 | 1.0 | 71.9 | 0.8 |
| 50-54 | 383 | 125.6 | 1.0 | 76.3 | 0.6 | 133 | 115.3 | 1.2 | 73.2 | 0.7 | 452 | 120.0 | 0.7 | 72.4 | 0.6 |
| 55-59 | 451 | 129.1 | 0.9 | 75.9 | 0.5 | 120 | 114.7 | 1.4 | 71.3 | 0.8 | 377 | 124.5 | 1.3 | 71.5 | 0.8 |
| 60-64 | 403 | 131.9 | 0.9 | 75.3 | 0.5 | 193 | 123.0 | 1.3 | 72.4 | 0.6 | 536 | 127.3 | 1.0 | 70.1 | 0.8 |
| 65-69 | 183 | 135.7 | 1.4 | 73.9 | 0.8 | 146 | 129.3 | 1.5 | 73.9 | 0.8 | 343 | 128.9 | 1.5 | 66.4 | 1.2 |
| 70-74 | 121 | 140.3 | 1.8 | 73.4 | 0.8 | 114 | 125.8 | 1.4 | 69.3 | 0.9 | 365 | 134.0 | 1.2 | 64.7 | 0.8 |
| 75-79 | 106 | 144.1 | 2.0 | 71.3 | 1.1 | 99 | 134.2 | 2.2 | 70.0 | 1.0 | 256 | 135.7 | 1.2 | 61.8 | 1.2 |
| All females | 3,830 | 123.7 | 0.4 | 73.1 | 0.2 | 1836 | 111.4 | 0.4 | 70.2 | 0.2 | 4970 | 118.1 | 0.4 | 69.0 | 0.4 |

Appendix 2. Mean Systolic (SBP) and Diastolic (DBP) Blood Pressure ( mm Hg ) among Hypertensive Individuals, by Awareness, Treatment and Control, and by Country.

|  |  | ENGLAND |  | CANADA |  | USA |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | SBP | DBP | SBP | DBP | SBP | DBP |
| Non hypertensive | mean | 119.9 | 71.2 | 109.3 | 71.1 | 114.8 | 69.3 |
|  | se | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 | 0.4 |
| All, Hypertensive | mean | 144.3 | 81.0 | 129.5 | 77.3 | 133.7 | 74.0 |
|  | se | 0.5 | 0.3 | 0.6 | 0.4 | 0.4 | 0.5 |
| All, Aware | mean | 141.7 | 78.5 | 126.1 | 75.2 | 130.8 | 72.3 |
|  | se | 0.6 | 0.4 | 0.6 | 0.4 | 0.4 | 0.5 |
| All, Treated | mean | 138.8 | 75.9 | 125.2 | 74.4 | 129.0 | 71.1 |
|  | se | 0.7 | 0.4 | 0.6 | 0.4 | 0.4 | 0.5 |
| Treated and Controlled | mean | 125.4 | 71.2 | 119.7 | 72.8 | 120.2 | 68.3 |
|  | se | 0.5 | 0.4 | 0.5 | 0.4 | 0.3 | 0.5 |
| Treated and not controlled | mean | 154.1 | 81.2 | 151.1 | 81.9 | 151.0 | 78.0 |
|  | se | 0.8 | 0.6 | 1.3 | 0.9 | 0.6 | 0.7 |
| Aware, not treated | mean | 151.5 | 88.1 | $147.2{ }^{\text {E }}$ | $93.8{ }^{\text {E }}$ | 149.3 | 85.1 |
|  | se | 0.8 | 0.6 | $2.5{ }^{\text {E }}$ | $2.0{ }^{\text {E }}$ | 1.2 | 1.1 |
| Unaware | mean | 149.3 | 85.5 | 146.7 | 87.6 | 146.1 | 81.5 |
|  | se | 0.5 | 0.5 | 1.0 | 0.7 | 0.6 | 1.3 |

${ }^{E}$ Interpret with caution (coefficient of variation $16.6 \%$ to $33.3 \%$ )
Hypertension: Systolic pressure $\geq 140$ or diastolic pressure $\geq 90$ or currently taking blood pressure lowering medication
Aware: Self-report of having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during pregnancy (England);
Self-reported blood pressure medication use in the past month or self-reported high blood pressure (Canada); Self-report of having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during pregnancy (USA)
Treated: Taking medication to lower blood pressure recorded by the nurse (England);Taking medication to lower blood pressure, self-report
(Canada, USA);
Treated and controlled: Taking medication to lower blood pressure and DBP $<90 \mathrm{~mm} \mathrm{Hg}$ and SBP $<140 \mathrm{~mm} \mathrm{Hg}$

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Treated and uncontrolled: Taking medication to lower blood pressure and DBP $>=90 \mathrm{~mm} \mathrm{Hg}$ or SBP $>=140 \mathrm{~mm} \mathrm{Hg}$ Aware, not treated: Self-reported of having been diagnosed as hypertensive by a doctor or nurse, not taking medication to lower blood pressure (England); Self-reported of having been told by health care provider that they have high blood pressure, not taking medication to lower blood pressure (Canada);Self-reported of having been told by health care provider that they have high blood pressure, not taking medication to lower blood pressure (USA)
Unaware: No self report of having been diagnosed as hypertensive by a doctor or nurse (England); No self report of having been told that they have high blood pressure and no self report of blood pressure medication use in the past month (Canada); No self report of having been told that they have high blood pressure (USA)

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

# Hypertension Prevalence, Awareness, Treatment, and Control in National Surveys from England, the USA, and Canada, and Correlation with Stroke and Ischemic Heart Disease Mortality 

Michel Joffres, professor of epidemiology ${ }^{1}$, Emanuela Falaschetti, research fellow in clinical trial statistics ${ }^{2}$, Cathleen Gillespie, senior statistician ${ }^{3}$, Cynthia Robitaille, epidemiologist ${ }^{4}$, Fleetwood Loustalot, epidemiologist ${ }^{3}$, Neil Poulter, professor ${ }^{5}$, Finlay A. McAlister, professor ${ }^{6}$, Helen Johansen, adjunct professor ${ }^{7}$, Oliver Baclic, medical advisor ${ }^{8}$, Norm Campbell, professor ${ }^{9}$
${ }^{1}$ Faculty of Health Sciences, Simon Fraser University, Burnaby, BC V5A 1S6, Canada.
${ }^{2}$ Imperial Clinical Trial Unit, School of Public Health, Imperial College London, St Mary’s Campus, Norfolk Place, W2 1PG London UK
${ }^{3}$ Division for Heart Disease and Stroke Prevention, Centers for Disease Control and Prevention, 4770 Buford Hwy NE, Mailstop F-72, Atlanta GA 30341
${ }^{4}$ Centre for Chronic Disease Prevention, Public Health Agency of Canada 785 Carling Avenue, A.L. 6806A, Ottawa, Ontario, Canada, K1A 0K9
${ }^{5}$ International Centre for Circulatory Health, Imperial College London, 59-61 North Wharf Road, London W2 1PG, UK
${ }^{6}$ Division of General Internal Medicine, University of Alberta Hospital 8440112 Street, Edmonton, Alberta T6G 2R7, Canada
${ }^{7}$ Department of Community Medicine and Epidemiology, University of Ottawa, Epidemiology \& Community Medicine, Room 3105, 451 Smyth Road, Ottawa, Ontario, Canada, K1H 8M5
${ }^{8}$ Public Health Agency of Canada, 130 Colonnade Rd, Ottawa, K1A0K9
${ }^{9}$ Departments of Medicine, Community Health Sciences and of Physiology and Pharmacology, Libin Cardiovascular Institute, University of Calgary, Canada Libin Cardiovascular Institute of Alberta, University of Calgary, 3280 Hospital Drive NW, Calgary Alberta, T2N 4Z6

Correspondance to: Michel Joffres mjoffres@sfu.ca

The Corresponding Author has the right to grant on behalf of all authors and does grant on behalf of all authors, an exclusive licence (or non exclusive for government employees) on a worldwide basis to the BMJ Publishing Group Ltd to permit this article (if accepted) to be published in BMJ editions and any other BMJPGL products and sublicences such use and exploit all subsidiary rights, as set out in our licence.

Competing Interests. All authors have completed the Unified Competing Interest form atwww.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; Dr. Poulter reports grants from Pfizer, grants from Hypertension Trust and personal fees from various Pharma companies, other from Servier, outside the submitted work; Dr Norm Campbell receives for salary support for a HSFC CIHR Chair in Hypertension Prevention and Control; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval was not required for these secondary analyses since all the original studies had their own ethical approval process.

Details of funding - No specific funding was provided for this study. Funding for NHANES comes from two primary sources: direct funding through the NCHS base budget and reimbursable funding from collaborating agencies; The Health Survey for England was funded by the National Health Centre; Health Canada and the Public Health Agency of Canada supported Statistics Canada in obtaining federal funding for for the Canadian Health Measures Survey. Other sources of support: FAM is supported by an Alberta Innovates Health Solutions Senior Health Scholar Award and the University of Alberta/Capital Health Chair in Cardiovascular Outcomes Research. NC holds the Heart and Stroke Foundation of Canada CIHR Chair in Hypertension Prevention and Control. NP is grateful for support from the NIHR Biomedical Research funding scheme and the NIHR Senior Investigator Award. Funding of the original surveys;

Statement of independence of researchers from funders - The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention, the Public Health Agency of Canada or the UK Department of Health.

Data sharing statement. All the authors had access to the original tables from the different studies. There is no additional data available.

Author's Contributions: Michel Joffres, Emanuela Falaschetti , Cathleen Gillespie, Cynthia Robitaille contributed to the data analysis, interpretation and writing.
Fleetwood Loustalot, Neil Poulter, Finlay A. McAlister, Helen Johansen, Oliver Baclic, and Norm Campbell contributed to the data interpretation and writing.

## Article Summary

1) Article focus

- Comparison of hypertension prevalence, awareness, treatment, and control in 3 National studies, England, USA, and Canada
- Correlation with stroke and ischemic heart disease mortality

2) Key messages

- Important variation by country
- Strong relationship between hypertension indicators and stroke mortality
- Gaps in the management of hypertension

3) Strengths and limitations

- Strengths
- National population data
- Detailed data on hypertension characteristics
- Strong correlation with meaningful outcome, mortality
- Limitations
- Data from England from 2006, but provide an important basis for measuring progress (current data not yet available)
- Limited to 3 countries
- Ecological correlation with mortality that excludes looking at confounders


#### Abstract

Objective Comparison of recent national survey data on prevalence, awareness, treatment and control of hypertension in England, the USA and Canada, and correlation of these parameters with each country stroke and ischemic heart disease (IHD) mortality.


Methods Non-instutionalized population surveys from England (2006), the USA (2007-2010) and Canada (2007-2009) using standardized protocols and devices. Analysis included individuals age 20-79 years. Stroke and IHD mortality rates were plotted against countries' specific prevalence data.

Results Mean systolic blood pressure (SBP) was higher in England than in the USA and Canada in all age-gender groups. Mean diastolic blood pressure (DBP) was similar in the three countries before age 50 and then fell more rapidly in the USA and was the lowest in the USA. Only $34 \%$ had a BP under 140/90 mmHg in England, compared with 50\% in the USA and 66\% in Canada. Prehypertension and stage 1 and 2 hypertension prevalence figures were the highest in England. Hypertension prevalence ( $\geq 140 \mathrm{mmHg}$ SBP and/or $\geq 90 \mathrm{mmHg}$ DBP) was lower in Canada (19.5\%) than in the USA (29\%) and England (30\%). Hypertension awareness was higher in both the USA (81\%) and Canada (83\%), than in England (65\%). England also had lower levels of hypertension treatment (51\%; USA 74\%; Canada 80\%) and control (< 140/90 mmHg; 27\%; USA 53\%; Canada 66\%). Canada had the lowest Stroke and IHD mortality rates, England the highest, and rates were inversely related to the mean SBP in each country and strongly related to blood pressure indicators, the strongest relationship being between low hypertension awareness and stroke mortality.

Conclusion While current prevention efforts in England should result in future improved figures, especially at younger ages, these data still show important gaps in the management of hypertension in these countries, with consequences on stroke and IHD mortality.

## Introduction

Increased blood pressure is the leading risk factor for premature death, stroke, and heart disease worldwide. ${ }^{1}$ In the year 2000, the world was estimated to have close to 1 billion people with hypertension and predicted an increase to 1.56 billion by 2025.2 ${ }^{2}$ The global economic burden of increased blood pressure was estimated to consume 370 billion US \$ worldwide and $10 \%$ of health care expenditures. ${ }^{3}$ Usual blood pressure is strongly and directly related to vascular and overall mortality without evidence of a threshold down to at least $115 / 75 \mathrm{mmHg}^{4}$ with small changes in blood pressure resulting in substantial changes in vascular disease. ${ }^{5}$

Based on clinical and population research, increased blood pressure, hypertension and hypertension related complications are largely preventable. Lifestyle changes can lower blood pressure and prevent hypertension while antihypertensive drug therapy can effectively reduce the cardiovascular events attributed to hypertension. ${ }^{1-6}$ Nevertheless, most people with hypertension worldwide are not effectively treated and controlled to recommended blood pressure targets. ${ }^{7}$ There are few national programs to serve as models for prevention and control of hypertension and few countries have embarked on national hypertension prevention and control programs. The United States (USA) blood pressure education program was established in $1972{ }^{8}$, while Canada (2000) and England (2004) have more recent initiatives. ${ }^{9,10}$ This manuscript compares recent data on prevalence, awareness, treatment and control of hypertension in England, the USA and Canada and correlates these hypertension-related parameters in the three countries to mortality from stroke and ischemic heart disease (IHD).

## Methods

Survey methods used in England, the USA, and Canada are summarized in Table 1. Detailed methodology for each survey is available elsewhere. ${ }^{11-13}$ Briefly, each survey is a representative sample of each country's non-institutionalized population and uses standardized protocols and
devices. While the England (2006) and Canada (2007-2009) surveys used automatic oscillometric devices, the USA (2007-2010) survey used mercury wall sphygmomanometer models. The number of blood pressure measurements available for analysis varied by count of blood pressure measures and survey protocols (Table 1).

In these analyses, hypertension was defined as a mean systolic blood pressure (SBP) $\geq 140 \mathrm{mmHg}$ or a mean diastolic blood pressure (DBP) $\geq 90 \mathrm{mmHg}$ or a respondent self-report of medication to lower blood pressure. Pre-hypertension (SBP 120-139 mmHg or DBP 80-89 mmHg), stage 1 (SBP $140-159 \mathrm{mmHg}$ or DBP $90-99 \mathrm{mmHg}$ ), and stage 2 (SBP $\geq 160 \mathrm{mmHg}$ or DBP $\geq 100 \mathrm{mmHg}$ ) hypertension were defined according to the Seventh Report of the Joint National Committee on the Prevention, Detection, Evaluation and Treatment of High Blood Pressure (JNC 7) definitions. ${ }^{6}$ Prevalence, awareness, treatment, control and awareness of hypertension were defined using commonly recognized standards. Prevalence was defined as SBP $\geq 140$ or DBP $\geq 90$ or currently taking medication to lower their blood pressure. Awareness was defined by self-report and included having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during pregnancy (England), medication to lower blood pressure in the past month or reported high blood pressure (Canada), or having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during pregnancy (USA). Treatment was defined as taking medication to lower blood pressure, as recorded by the nurse (England), or a self-report of taking medication to lower blood pressure (Canada, USA). Treated and controlled was defined as taking medication to lower blood pressure and SBP $<140 \mathrm{mmHg}$ and $\mathrm{DBP}<90 \mathrm{mmHg}$; treated and uncontrolled a SBP $\geq 140 \mathrm{mmHg}$ or DBP $\geq 90 \mathrm{mmHg}$ while on medication to lower blood pressure. Aware, yet not treated, was defined by self-report and included having been diagnosed as hypertensive by a doctor or nurse (England) / health care provider (Canada, USA), and not taking medication to lower blood pressure.

Survey data were not age and sex standardized. They represent the current country-specific figures, and therefore correspond more precisely to each country's crude mortality rates for stroke and IHD. All prevalence figures are weighted using survey weights to represent each country's population. Standard errors were computed taking into account each country's sampling methodology. ${ }^{11-13}$ To be comparable across the three surveys, the analysis was restricted to individuals age 20-79 years and excluded pregnant women. The Canadian Health Measures Survey (CHMS) data analysis was performed using SAS® Enterprise Guide (Version 4.1, SAS Institute Inc., Cary, NC, 2006). The Health Survey for England (HSE) data analysis was performed using SPSS 19. The National Health and Nutrition Examination Survey (NHANES) data analysis was performed using SAS version 9.2 and SAS-Callable SUDAAN version 10 (RTI International)], to account for the complex sampling design.

The latest WHO country specific mortality data available were from 2008 for Canada and the USA ${ }^{14}$ and we used 2006 data for England. ${ }^{15}$ Crude mortality rates per 100,000 were obtained for men and women for stroke and ischemic heart disease (IHD) and plotted against country specific prevalence data for hypertension awareness, treatment, and control.

## Results

The distribution of SBP and DBP by sex, age, and country shows an increase in SBP with age and an increase, plateau and decrease of DBP with aging (Figure 1; Appendix 1 Table). SBP is higher in men than women in the younger age groups and becomes higher in women than men after age 60 years in Canada and age 70 years in England and USA. Mean SBP is overall higher in England than in the USA and Canada in all age-gender groups. DBP is similar in the 3 countries before age 50 and then falls more rapidly in the USA and is overall lower in men and women from the USA. The distribution of measured blood pressure (including treated individuals), by level, in Table 2 reflects the findings in Figure 1. Only 34\% of adults aged 20-79 years would be classified as having
a normal blood pressure ( $<120 / 80 \mathrm{mmHg}$ ) in England, compared with 50\% in the USA and 66\% in Canada. Pre-hypertension and stage 1 and 2 hypertension prevalence figures are also much higher in England than in the USA and Canada.

The prevalence of hypertension, and awareness, treatment, and control levels among those with hypertension are shown in Table 3. The prevalence of hypertension is lowest in Canada (19.5\%) and higher in the USA (29\%) and England (30\%). Hypertension awareness is close to $80 \%$ in both the USA (81\%) and Canada (83\%) and lower in England (65\%). England also has lower levels of hypertension treatment (England 51\%; USA 74\%; Canada 80\%) and control (England 27\%; USA $53 \%$; Canada $66 \%$ ). These patterns are similar in the different age and sex sub groups (Table 3). Among individuals treated for hypertension (i.e., taking medication to lower blood pressure), the proportion being controlled is lowest in England (53\%), while 71\% in the USA and 82\% in Canada are controlled.

The mean SBP and DBP are provided in Appendix 2 by the different prevalence categories of Table 3. The data are consistent with those in the previous tables showing the highest SBP mean in England in all categories. For DBP, England has also higher means than the USA and Canada among all hypertensives and aware and treated categories.

At the time when these surveys were conducted, Canada had the lowest stroke and IHD mortality rates while England had the highest. Rates of both outcomes were inversely related to the mean SBP in each country (Figure 2). We found a strong relationship between the selected blood pressure indicators and stroke and IHD mortality, the strongest relationship being between hypertension awareness and stroke mortality, especially in women (Figure 3). Stroke rates were higher in women than men for any level of each of the BP indicators and the opposite was true for IHD (Figure 2-3).

## Discussion

Although all 3 countries evaluated have had substantive improvement in most hypertension treatment indicators over the past two decades ${ }^{16-20}$, this study found marked differences in hypertension prevalence, awareness, treatment and control rates in England, the USA, and Canada. Canada has the lowest prevalence of hypertension at 19\% followed by England and United States at about $30 \%$ each. A previous study based on earlier cycles of these surveys also found little difference in the prevalence of hypertension between England and the USA. ${ }^{21}$ The main determinants of hypertension are known. These include poor dietary habits, excess sodium intake, physical inactivity, obesity, excess alcohol consumption, as well as age, gender, race and sociodemographic factors. The national differences in prevalence are likely related to differences in the interaction between these determinants as well as differences in the clinical systems, community programs, and environmental and policy supports for hypertension prevention and management. Compared to the USA, Canada has a lower rate of obesity but to our knowledge there has never been a comprehensive comparison of the determinants of blood pressure using appropriately adjusted data in these countries. A comprehensive comparison of the determinants of hypertension and the policies that fail to address adverse differences in the modifiable determinants would be an important next step. This is also important since these data show an important difference in the younger age groups between England, Canada and the USA. Since blood pressure tracks with age ${ }^{22}$, efforts to influence the determinants of hypertension are essential to reduce hypertension prevalence in the older age groups. The recent decrease in childhood obesity in England ${ }^{23}$ should be followed by a reduction in blood pressure in the next surveys. Our study has also found important differences in the awareness, treatment and control of hypertension in the three countries. England, the USA, and Canada all have developed differing approaches to improve hypertension treatment and control. In the USA, several diverse approaches have been taken. $6,8,24$ Historically the USA has had one of the world's highest rates of hypertension awareness, treatment and control and has also seen improvements in these indicators
with intensified efforts; ${ }^{18}$ however, despite broad clinical and community efforts, over half of adults with hypertension are uncontrolled based on current guidelines. ${ }^{19}$ Recent national activities and recommendations are staged to positively impact hypertension estimates. 25-29

Importantly, we also found national-level differences in mortality rates from stroke and IHD, which paralleled the differences in hypertension awareness, treatment, and control between these 3 countries. Both stroke and IHD mortality were strongly inversely correlated with mean SBP in each country.

Efforts in England have included episodic national hypertension recommendations developed by the British Hypertension Society (B.H.S - a non-governmental organization of specialists and researchers) with the recommendations more recently being developed by a governmental organization in collaboration with the BHS. ${ }^{30}$ Implementation programs have included an extensive public program to educate people on the risks of salt for hypertension ${ }^{31}$ and also to an extensive government program to pay General Practitioners bonus payments for achieving benchmarks for hypertension care ${ }^{32}$ - although the efficacy of payment for performance for improving hypertension control has been questioned. ${ }^{33}$

In 2000, Canada launched an annually updated hypertension recommendations program (Canadian Hypertension Education Program (CHEP)). ${ }^{9}$ In 2006, the program was assisted by an extensive initiative to inform the public about hypertension and the health risks and opportunities to reduce dietary salt. ${ }^{34}$ The introduction of CHEP in Canada is temporally related to improvements in management patterns and has been also temporally associated with reduced CVD in Canada. ${ }^{35}$ It is difficult to assess how much the different national approaches to hypertension detection and management impact on the differences observed in our study. British Guidelines in place in $2006^{10,39}$ and since ${ }^{30}$ do not recommend the routine use of antihypertensive treatment for those with a systolic BP >140 mmHg and/or diastolic BP $>90 \mathrm{mmHg}$, rather only if such people have an estimated 10 year CV risk of $>20 \%$. Consequently treatment rates and control rates might be
expected to be lower in England than in the USA \& Canada. Furthermore, in England, the National Institute for Health and Clinical Excellence's Quality and Outcomes Framework, which includes measures used in the calculation of provider reimbursement, included a higher blood pressure target ( $<150 / 90$ ) during the period of data used for these analyses. This will be lowered (to $<140 / 90$ ) in 2013/2014 to align with national guidelines. In addition to the new National Institute for Health and Clinical Excellence (NICE) guidelines ${ }^{30}$, the national salt reduction program in England would be expected to result in further reductions in the prevalence of hypertension and improvement in hypertension treatment indicators in the recent and future years as Canadian and Finnish data suggest. ${ }^{36,37}$

There are several potential limitations to our current analyses. In addition to low response rates and hence small numbers in some strata, each country uses different methodology to assess blood pressure and relatively small differences in blood pressure can impact hypertension indicators. In particular Canada has adopted the use of a fully automated blood pressure device that operates in the absence of an observer and averages the last 5 of six blood pressure readings. The Canadian method reduces the influence of the observer (white coat effect) on blood pressure and results in a slightly lower average blood pressure than a single auscultatory blood pressure reading.

Nevertheless using an algorithm to adjust the data in the Canadian survey ${ }^{38}$ to represent single manual reading results in little change in the major hypertension indicators as the difference in methods at the therapeutic cut point of $140 / 90 \mathrm{mmHg}$ is relatively small, but might reduce the differences between the US and Canada. The close relationship between stroke mortality and hypertension prevalence and hypertension indicators suggest that blood pressure and hypertension differences seen in this study are real and biologically important. We acknowledge the limitation of using three points for our mortality graphs, which require a high level of correlation to be statistically significant.

We did not use age- or gender-adjusted data from the different countries. The lack of adjustment was intended so that hypertension risk factors could be directly compared to stroke mortality for each country. In addition, in a separate analysis, comparison of age-adjusted data to a common standard population showed very little difference with the current figures. We were not able to obtain more recent common mortality data than 2008 for all countries. There is some overlap between the timing of the US and Canadian surveys, but the English survey was conducted more than one year earlier. Management of hypertension in England is likely to have improved since 2006. Increased blood pressure and hypertension represent major global threats to population health, with stroke and IHD being the most closely related adverse outcomes. ${ }^{4}$ Interventions to lower average population blood pressure and interventions to identify and control blood pressure in those with hypertension are critical to prevent blood pressure related complications. ${ }^{2-6}$ Nevertheless, hypertension control rates are low even in developed countries and most countries do not have formal programs to control hypertension. ${ }^{40}$ Further, population surveys indicate that approximately $29 \%$ of men and $25 \%$ of women have uncontrolled hypertension with increasing numbers of hypertension cases globally due to population growth and ageing. ${ }^{41}$ Hence, countries worldwide should consider introducing and evaluating coordinated programs to improve the prevention, detection, awareness, treatment, and control of hypertension, and our data suggest that the more assertive approach apparent in North America is associated with large benefits in terms of reduced cardiovascular mortality. A greater focus on prevention of high blood pressure in the younger age groups is also necessary.

## References

1. WHO. World Health Organization, World Health Statistics 2012. World Health Organization, Geneva 2012 . Available at
http://www.who.int/gho/publications/world_health_statistics/2012/en/index.html. Accessed April 2013.
2. 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.
3. Gaziano TA, Bitton A, Anand S, Weinstein MC; International Society of Hypertension. The global cost of nonoptimal blood pressure. J Hypertens. 2009; 27: 1472-7.
4. Lewington S, Clarke R, Qizilbash N, Peto R, Collins R; Prospective Studies Collaboration. Agespecific 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.
5. Law MR, Morris JK, Wald NJ. Use of blood pressure lowering drugs in the prevention of cardiovascular disease: meta-analysis of 147 randomised trials in the context of expectations from prospective epidemiological studies. BMJ. 2009; 338: b1665.
6. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL Jr, 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.
7. Kearney PM, Whelton M, Reynolds K, Whelton PK, He J. Worldwide prevalence of hypertension: a systematic review. J Hypertens 2004; 22: 11-19
8. National Heart Lung and Blood Institute. National High Blood Pressure Education Program. Available at http://www.nhlbi.nih.gov/about/nhbpep/index.htm. Accessed April 2013.
9. McAlister FA. The Canadian Hypertension Education Program (CHEP)—a unique Canadian initiative. Can J Cardiol 2006; 22: 559-564.
10. National Institute for Health and Clinical Excellence. Hypertension: Clinical management of primary hypertension in adults. Clinical guidelines, CG127 - Issued: August 2011. Available at http://guidance.nice.org.uk/CG127. Accessed April 2013.
11. CDC. National Health and Nutrition Examination Survey Data. Hyattsville, MD: US Department of Health and Human Services, CDC; 2010. Available at http://www.cdc.gov/nchs/nhanes/about_nhanes.htm. Accessed April 2013.
12. Craig R, Mindell J, eds. Health Survey for England 2006. London, United Kingdom: The Information Centre; 2008.
13. The Canadian Health Measures Survey: Rationale background and overview. Available at http://www.statcan.gc.ca/pub/82-003-s/82-003-s2007000-eng.htm. Accessed April 2013.
14. Causes of Death 2008 Summary Tables, May 2011. Health statistics and informatics Department, World Health Organization, Geneva, Switzerland. Available at http://www.who.int/evidence/bod. Accessed April 2013.
15. Mortality Statistics Newport: Office for National Statistics. Deaths registered in 2006. Review of the Registrar General on deaths in England and Wales, 2006.
http://www.ons.gov.uk/ons/rel/vsob1/mortality-statistics--deaths-registered-in-england-and-wales--series-dr-/2006/data-tables--2006.zip. Accessed April 2013.
16. Wilkins K, Campbell NRC, Joffres MR, McAlister FA, Nichol M, Quach S, et al. Blood pressure in Canadian adults. Health Reports. 2010: 21: 1-10.
17. Falaschetti E, Chaudhury M, Mindell J, Poulter NR. Continued Improvement In Hypertension Management In England: Results From The Health Survey For England 2006. Hypertension 2009; 53: 480-86.
18. Egan BM, Zhao Y, Axon RN. US trends in prevalence, awareness, treatment, and control of hypertension, 1988-2008. JAMA. 2010; 303: 2043-50.
19. Centers for Disease Control and Prevention (2012). Vital Signs: Awareness and treatment of uncontrolled hypertension among adults - United States, 2003-2010 Morbidity and Mortality Weekly Report; 61, 703-709.
20. McAlister FA, Wilkins K, Joffres M, Leenen FH, Fodor G, Gee M, et al. Changes in the rates of awareness, treatment and control of hypertension in Canada over the past two decades. CMAJ. 2011; 183: 1007-13.
21. Martinson ML, Teitler JO, Reichman NE. Health across the lifespan in the United States and England. Am J Epidemiol 2011; 173: 858-65.
22. Cheng S, Xanthakis V, Sullivan LM, Vasan RS. Blood pressure tracking over the adult life course: patterns and correlates in the Framingham heart study. Hypertension. 2012; 60: 1393-9.
23. Lien N, Henriksen HB, Nymoen LL, Wind M, Klepp KI. Availability of data assessing the prevalence and trends of overweight and obesity among European adolescents. Public Health Nutr. 2010; 13: 1680-7.
24. United States Preventive Services Task Force. Recommendations. Available at http://www.uspreventiveservicestaskforce.org/recommendations.htm. Accessed April 2013.
25. Centers for Disease Control and Prevention (2011). Million Hearts: Strategies to reduce the prevalence of leading cardiovascular disease risk factors, United States, 2011. Morbidity and Mortality Weekly Report. 60; 1248-1251.
26. Centers for Disease Control and Prevention. Sodium Reduction in Communities Program. Available at http://www.cdc.gov/dhdsp/programs/sodium_reduction.htm. Accessed April 2013.
27. Centers for Disease Control and Prevention. Community Transformation Grant Program. Available at http://www.cdc.gov/communitytransformation/. Accessed April 2013.
28. U.S. Department of Health and Human Services, U.S. Department of Agriculture. Dietary Guidelines for Americans, 2010. 7th ed. Washington DC. 2011.
29. Institute of Medicine. A population-based policy and systems change approach to prevent and control hypertension. National Academy of Sciences. Washington DC. 2010.
30. National Institute for Health and Clinical Excellence. Hypertension: clinical management of primary hypertension in adults. Clinical guidelines, CG127. http://guidance.nice.org.uk/CG127. Accessed April 2013.
31. National Institute for Health and Clinical Excellence. Prevention of cardiovascular disease at the population level. Public health guidance, PH2; June 2010. Available at http://guidance.nice.org.uk/PH25. Accessed April 2013.
32. Doran T, Fullwood C, Gravelle H, Reeves D, Kontopantelis E, Hiroeh U, et al. Pay-forPerformance Programs in Family Practices in the United Kingdom. N Engl J Med 2006; 355: 375-384.
33. Serumaga B, Ross-Degnan D, Avery AJ, Elliott RA, Majumdar SR, Zhang F, et al. Effect of pay for performance on the management and outcomes of hypertension in the United Kingdom: interrupted time series study. BMJ. 2011; 342: d108
34. Campbell N, Young E, Drouin D, Legowski B, Adams MA, Farrell J, et al. A framework for discussion on how to improve prevention, management and control of hypertension in Canada. Can J Cardiol. 2012; 28: 262-69
35. McAlister FA, Feldman RD, Wyard K, Brant R, Campbell NR; CHEP Outcomes Research Task Force. The impact of the Canadian Hypertension Education Programme in its first decade. Eur Heart J. 2009; 30: 1434-9.
36. Joffres MR, Campbell NR, Manns B, Tu K. Estimate of the benefits of a population-based reduction in dietary sodium additives on hypertension and its related health care costs in Canada. Can J Cardiol. 2007; 23: 437-43.
37. Karppanen H, Mervaala E. Sodium intake and hypertension. Prog Cardiovasc Dis. 2006; 49: 5975.
38. Myers MG, McInnis NH, Fodor GJ, Leenen FH. Comparison between an automated and manual sphygmomanometer in a population survey. Am J Hypertens 2008; 21: 280-3.
39. National Institute for Health and Clinical Excellence. Hypertension: management of hypertension in adults in primary care. Clinical guidelines, CG34; June 2006. Available at www.nice.org.uk/nicemedia/pdf/CG034NICEguideline.pdf. Accessed April 2013.
40. Pereira M, Lunet N, Azevedo A, Barros H. Differences in prevalence, awareness, treatment and control of hypertension between developing and developed countries. J Hypertens. 2009; 27: 963-75.
41. Danaei G, Finucane MM, Lin JK, Singh GM, Paciorek CJ, Cowan MJ, et al. Global Burden of Metabolic Risk Factorsof Chronic Diseases Collaborating Group (Blood Pressure). National, regional, and global trends in systolic blood pressure since 1980: systematic analysis of health examination surveys and epidemiological studies with 786 country-years and $5 \cdot 4$ million participants. Lancet. 2011; 377: 568-77.

Table 1. Survey methods, by country.

| Country | Years of Survey | Sampling | $n$ | Age Range | Response Rate |
| :---: | :---: | :---: | :---: | :---: | :---: |
| England | 2006 | Multistage | 6,873 | 20-79 | 68\% household response rate, 88\% individual response rate in co-operating households and $66 \%$ with nurse visit (examination response rate). |
| Canada | 2007-2009 | Multistage | 3,485 | 20-79 | Household response rate $=$ 70\% <br> Individual response rate to the household questionnaire $=$ 88\% Examination response rate $=85 \%$ |
| US | 2007-2010 | Multistage | 10,003 | 20-79 | Interview response rate $=79 \%$ <br> Examination response rate $=$ 76\% <br> $93 \%$ of those examined had $\geq 2$ <br> blood pressure measurements |
| Country | Blood Pressure Device | Technician | N of Blood Pressure Measures | Study Protocol Used |  |
| England | Omron HEM 907 | Nurse | 3 | Mean of second and third measures taken 1 minute apart after 5 minutes rest |  |
| Canada | Bp TRUTM ${ }^{\text {™ }}$ 300* | Health measures specialists | 6 | Average of last 5 of 6 measures taken one minute apart after a 5 minute rest period <br> Mean of second and third measurement taken 30 seconds apart after resting quietly in a sitting position for 5 minutes ${ }^{\dagger}$ |  |
| US | Calibrated ${ }^{\circledR}$ VLok ${ }^{\circledR}$ cuff, Latex Inflation Bulb, Air-Flo® Control Valve. <br> Baumanometer® calibrated mercury wall model. | Physician | 3 |  |  |

[^2]Figure 1. Distribution of Systolic and Diastolic Blood Pressure by Country, Age and Sex.


Table 2. Distribution of Measured Blood Pressure by Level, Sex, Age, and Country.

|  | Total | Normal |  | Pre- <br> Hypertension |  |  |  | Stage 1 |  | Stage 2 |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | n | \% | se | n | \% | se | n | \% | se | n | \% | se |
| $\begin{gathered} \text { ENGLAND } \\ \text { All } \end{gathered}$ | 7,382 | 2,528 | 34.2 | 0.7 | 3,242 | 43.9 | 0.7 | 1235 | 16.7 | 0.5 | 376 | 5.1 | 0.3 |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Males | 3,555 | 761 | 21.4 | 0.8 | 1,903 | 53.5 | 0.9 | 709 | 19.9 | 0.7 | 182 | 5.1 | 0.4 |
| Females | 3,826 | 1,767 | 46.2 | 0.9 | 1,339 | 35 | 0.9 | 526 | 13.7 | 0.6 | 195 | 5.1 | 0.4 |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-39 | 2,618 | 1,273 | 48.6 | 1.2 | 1,115 | 42.6 | 1.1 | 210 | 8 | 0.6 | 20 | 0.8 | 0.2 |
| 40-59 | 2,962 | 966 | 32.6 | 0.9 | 1,360 | 45.9 | 0.9 | 482 | 16.3 | 0.7 | 155 | 5.2 | 0.4 |
| 60-79 | 1,801 | 289 | 16.1 | 1 | 767 | 42.6 | 1.5 | 543 | 30.2 | 1.3 | 201 | 11.2 | 0.9 |
| CANADA |  |  |  |  |  |  |  |  |  |  |  |  |  |
| All | 3,485 | 2,214 | 66.1 | 1.7 | 955 | 27.2 | 1.4 | 259 | 5.4 | 0.3 | 57 | $1.3{ }^{\text {E }}$ | $0.2{ }^{\text {E }}$ |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Males | 1,649 | 951 | 60.6 | 2.4 | 538 | 32.9 | 2.2 | 140 | 5.9 | 0.5 | 20 | 0.7E | $0.2{ }^{\text {E }}$ |
| Females | 1,836 | 1,263 | 71.6 | 1.4 | 417 | 21.6 | 1.1 | 119 | 4.8 | 0.6 | 37 | $2.0{ }^{\text {E }}$ | $0.5{ }^{\text {E }}$ |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-39 | 1,159 | 992 | 84.0 | 1.9 | 155 | 15.2 | 1.8 | F | F | F | F | F | F |
| 40-59 | 1,231 | 785 | 63.4 | 3.3 | 351 | 30.2 | 2.8 | 81 | 5.3 | 0.7 | 14 | $1.1{ }^{\text {E }}$ | $0.3{ }^{\text {E }}$ |
| 60-79 | 1,095 | 437 | 39.4 | 2.0 | 449 | 42.9 | 2.2 | 168 | 13.8 | 1.1 | 41 | 3.9E | $1.0^{\mathrm{E}}$ |
| USA |  |  |  |  |  |  |  |  |  |  |  |  |  |
| All | 10,003 | 4,663 | 50.3 | 0.8 | 3,615 | 36.0 | 0.7 | 1,296 | 11.0 | 0.4 | 429 | 2.7 | 0.2 |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Males | 5,033 | 1,998 | 42.2 | 1.0 | 2,109 | 42.7 | 1.0 | 713 | 12.2 | 0.6 | 213 | 2.8 | 0.3 |
| Females | 4,970 | 2,665 | 58.3 | 1.0 | 1,506 | 29.3 | 0.8 | 583 | 9.7 | 0.5 | 216 | 2.7 | 0.2 |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-39 | 3,394 | 2,210 | 65.2 | 1.1 | 1,007 | 29.7 | 1.1 | 148 | 4.4 | 0.4 | 29 | 0.7 | 0.1 |
| 40-59 | 3,586 | 1,608 | 46.5 | 1.3 | 1,371 | 39.1 | 1.1 | 473 | 11.9 | 0.7 | 134 | 2.6 | 0.3 |
| 60-79 | 3,023 | 845 | 30.8 | 1.3 | 1,237 | 41.3 | 1.2 | 675 | 21.2 | 1.1 | 266 | 6.7 | 0.5 |

${ }^{\text {E }}$ Interpret with caution (coefficient of variation $16.6 \%$ to $33.3 \%$ )
${ }^{\mathrm{F}}$ Too unreliable to be reported (coefficient of variation greater than 33.3\%)
Normal: Systolic $<120$ and diastolic $<80$. Pre-Hypertension: $120 \leq$ Systolic $<140$ or $80 \leq$ diastolic $<90$. Stage 1 :
$140 \leq$ Systolic $<160$ or $90 \leq$ diastolic $<100$. Stage 2 : Systolic $\geq 160$ or diastolic $\geq 100$. Regardless of medication use

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml 20

Table 3. Hypertension Prevalence and Percentage with Hypertension, Aware, Treated, Controlled, by sex, age group, and country.

|  | Prevalence |  | Aware |  | Treated |  | Treated \& Controlled |  | Treated \& not controlled |  | Aware, not treated |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | \% | SE | \% | SE | \% | SE | \% | SE | \% | SE | \% | SE |
| $\begin{aligned} & \text { ENGLAND } \\ & \text { All } \end{aligned}$ | 30.0 | 0.7 | 65.3 | 1.2 | 51.3 | 1.2 | 27.3 | 1.1 | 23.9 | 0.9 | 14.1 | 0.8 |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |
| Male | 32.9 | 0.9 | 60.6 | 1.5 | 45.1 | 1.6 | 23.9 | 1.4 | 21.2 | 1.2 | 15.5 | 1.1 |
| Female | 27.3 | 0.8 | 70.7 | 1.5 | 58.2 | 1.6 | 31.1 | 1.6 | 27 | 1.4 | 12.5 | 1.1 |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-39 | 9.3 | 0.7 | 35 | 3.1 | 10.6 | 2.1 | 5 | 1.4 | 5.6 | 1.7 | 24.4 | 2.9 |
| 40-59 | 27.9 | 0.8 | 59.3 | 1.7 | 40.8 | 1.8 | 23.1 | 1.5 | 17.7 | 1.2 | 18.5 | 1.3 |
| 60-80 | 63.7 | 1.3 | 76.1 | 1.6 | 67.4 | 1.7 | 35.1 | 1.8 | 32.3 | 1.6 | 8.7 | 0.9 |
| CANADA |  |  |  |  |  |  |  |  |  |  |  |  |
| All | 19.5 | 0.6 | 83.4 | 1.8 | 79.9 | 2.0 | 65.8 | 2.0 | 14.0 | 2.0 | $3.5{ }^{\text {E }}$ | $0.9{ }^{\text {E }}$ |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |
| Male | 19.7 | 1.1 | 80.4 | 2.2 | 76.5 | 2.1 | 66.8 | 3.0 | $9.7{ }^{\text {E }}$ | $2.0{ }^{\text {E }}$ | 3.9 E | 0.9 E |
| Female | 19.3 | 0.6 | 86.5 | 2.0 | 83.3 | 2.4 | 64.9 | 2.8 | $18.4{ }^{\text {E }}$ | $3.2{ }^{\text {E }}$ | F | F |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-39 | $2.0^{\text {E }}$ | $0.6{ }^{\text {E }}$ | 64.4 | 9.8 | $58.4{ }^{\text {E }}$ | $10.3{ }^{\text {E }}$ | $56.8{ }^{\text {E }}$ | $10.6{ }^{\text {E }}$ | F | F | F | F |
| 40-59 | 18.4 | 1.5 | 80.4 | 2.7 | 73.4 | 3.7 | 65.4 | 3.8 | $8.0{ }^{\text {E }}$ | $1.8{ }^{\text {E }}$ | $7.0{ }^{\text {E }}$ | $2.3{ }^{\text {E }}$ |
| 60-79 | 53.2 | 2.4 | 86.7 | 1.8 | 85.7 | 2.1 | 66.8 | 1.8 | 19.0 | 2.6 | F | F |
| USA |  |  |  |  |  |  |  |  |  |  |  |  |
| All | 29.1 | 0.8 | 81.1 | 1.0 | 74.0 | 1.1 | 52.8 | 1.0 | 21.2 | 0.7 | 7.0 | 0.7 |
| Sex |  |  |  |  |  |  |  |  |  |  |  |  |
| Male | 29.4 | 1 | 77.7 | 1.4 | 69.1 | 1.5 | 48.7 | 1.6 | 20.3 | 1.1 | 8.6 | 1 |
| Female | 28.8 | 0.9 | 84.6 | 1.2 | 79.1 | 1.4 | 57 | 1.5 | 22.1 | 1 | 5.5 | 0.7 |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |
| 20-39 | 7.7 | 0.6 | 61.1 | 4.6 | 47.2 | 4.0 | 35.0 | 3.6 | 12.2 | 2.4 | 13.9 | 2.5 |
| 40-59 | 31.1 | 1.2 | 82.4 | 1.4 | 73.1 | 1.8 | 53.5 | 1.7 | 19.6 | 1.3 | 9.4 | 1.0 |
| 60-79 | 63.6 | 1.3 | 84.2 | 1.3 | 80.9 | 1.4 | 56.1 | 1.5 | 24.8 | 0.9 | 3.3 | 0.6 |

${ }^{\text {E }}$ Interpret with caution (coefficient of variation $16.6 \%$ to $33.3 \%$ )
${ }^{\text {F }}$ Too unreliable to be reported (coefficient of variation greater than 33.3\%)
Hypertension: Systolic pressure $\geq 140$ or diastolic pressure $\geq 90$ or currently taking blood pressure lowering medication Awareness, treatment and control were assessed among those with hypertension.

Aware: Self-report of having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during
pregnancy (ENGLAND); Self-reported BP medication use in the past month or self-reported high blood pressure (Canada); Self-report of having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during pregnancy (USA)
Treated: Taking medication to lower blood pressure recorded by the nurse (ENGLAND);Taking medication to lower blood pressure, self-report (Canada, USA);
Treated and controlled: Taking medication to lower blood pressure and $\mathrm{DBP}<90 \mathrm{~mm} \mathrm{Hg}$ and $\mathrm{SBP}<140 \mathrm{~mm} \mathrm{Hg}$ Treated and uncontrolled: Taking medication to lower blood pressure and DBP $>=90 \mathrm{~mm} \mathrm{Hg}$ or SBP $>=140 \mathrm{~mm} \mathrm{Hg}$ Aware, not treated: Self-reported of having been diagnosed as hypertensive by a doctor or nurse, not taking medication to lower blood pressure (ENGLAND); Self-reported of having been told by health care provider that they have high blood pressure, not taking medication to lower blood pressure (Canada);Self-reported of having been told by health care provider that they have high blood pressure, not taking medication to lower blood pressure (USA)
Unaware: No self report of having been diagnosed as hypertensive by a doctor or nurse (ENGLAND); No self report of having been told that they have high blood pressure and no self report of BP medication use in the past month (Canada); No self report of having been told that they have high blood pressure (USA)

Figure 2. Stroke and Ischemic Heart Disease (IHD) Mortality* by Country Mean SBP

*2008 mortality rate per 100,000 (WHO) for USA and Canada; 2006 Statistics for England and Wales.

Figure 3. Stroke and IHD mortality by Country Prevalence of Hypertension Awareness, Treatment and Control

*2008 mortality rate per 100,000 (WHO) for USA and Canada; 2006 Statistics for England and Wales.

Appendix 1. Mean Systolic and Diastolic Blood Pressure by Sex, Age, and Country.

Appendix 2. Mean Systolic (SBP) and Diastolic (DBP) Blood Pressure (mm Hg) among Hypertensive Individuals, by Awareness, Treatment and Control, and by Country.

|  |  | ENGLAND |  | CANADA |  | USA |  |
| :---: | :---: | :---: | ---: | ---: | ---: | ---: | ---: |
|  |  | SBP | DBP | SBP | DBP | SBP | DBP |
| Non hypertensive | mean | 119.9 | 71.2 | 109.3 | 71.1 | 114.8 | 69.3 |
|  | se | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 | 0.4 |
| All, Hypertensive | mean | 144.3 | 81.0 | 129.5 | 77.3 | 133.7 | 74.0 |
|  | se | 0.5 | 0.3 | 0.6 | 0.4 | 0.4 | 0.5 |
| All, Aware | mean | 141.7 | 78.5 | 126.1 | 75.2 | 130.8 | 72.3 |
|  | se | 0.6 | 0.4 | 0.6 | 0.4 | 0.4 | 0.5 |
| All, Treated | mean | 138.8 | 75.9 | 125.2 | 74.4 | 129.0 | 71.1 |
|  | se | 0.7 | 0.4 | 0.6 | 0.4 | 0.4 | 0.5 |
| Treated and Controlled | mean | 125.4 | 71.2 | 119.7 | 72.8 | 120.2 | 68.3 |
|  | se | 0.5 | 0.4 | 0.5 | 0.4 | 0.3 | 0.5 |
| Treated and not | mean | 154.1 | 81.2 | 151.1 | 81.9 | 151.0 | 78.0 |
| controlled | se | 0.8 | 0.6 | 1.3 | 0.9 | 0.6 | 0.7 |
| Aware, not treated | mean | 151.5 | 88.1 | $147.2^{\mathrm{E}}$ | $93.8^{\mathrm{E}}$ | 149.3 | 85.1 |
|  | se | 0.8 | 0.6 | $2.5^{\mathrm{E}}$ | $2.0^{\mathrm{E}}$ | 1.2 | 1.1 |
| Unaware | mean | 149.3 | 85.5 | 146.7 | 87.6 | 146.1 | 81.5 |
|  | se | 0.5 | 0.5 | 1.0 | 0.7 | 0.6 | 1.3 |

${ }^{\text {E }}$ Interpret with caution (coefficient of variation 16.6\% to 33.3\%)
Hypertension: Systolic pressure $\geq 140$ or diastolic pressure $\geq 90$ or currently taking blood pressure lowering medication Aware: Self-report of having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during pregnancy (England); Self-reported blood pressure medication use in the past month or self-reported high blood pressure (Canada); Self-report of having been diagnosed as hypertensive by a doctor or nurse, excluding women diagnosed during pregnancy (USA)

Treated: Taking medication to lower blood pressure recorded by the nurse (England);Taking medication to lower blood pressure, self-report (Canada, USA);
Treated and controlled: Taking medication to lower blood pressure and DBP $<90 \mathrm{~mm} \mathrm{Hg}$ and SBP $<140 \mathrm{~mm} \mathrm{Hg}$
Treated and uncontrolled: Taking medication to lower blood pressure and DBP $>=90 \mathrm{~mm} \mathrm{Hg}$ or SBP $>=140 \mathrm{~mm} \mathrm{Hg}$ Aware, not treated: Self-reported of having been diagnosed as hypertensive by a doctor or nurse, not taking medication to lower blood pressure (England); Self-reported of having been told by health care provider that they have high blood pressure, not taking medication to lower blood pressure (Canada);Self-reported of having been told by health care provider that they have high blood pressure, not taking medication to lower blood pressure (USA)
Unaware: No self report of having been diagnosed as hypertensive by a doctor or nurse (England); No self report of having been told that they have high blood pressure and no self report of blood pressure medication use in the past month (Canada); No self report of having been told that they have high blood pressure (USA)

## STROBE Statement-Checklist of items that should be included in reports of cross-sectional studies Item No <br> Recommendation

Title and abstract 1 (a) Indicate the study's design with a commonly used term in the title or the abstract Done 'National Surveys'
(b) Provide in the abstract an informative and balanced summary of what was done and what was found

Done

| Introduction |  |  |
| :--- | :--- | :--- |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported <br> Done |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses <br> Done |
| Methods | 4 | Present key elements of study design early in the paper <br> Done |
| Study design | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, <br> exposure, follow-up, and data collection <br> Done |
| Setting |  |  |


| Participants | 6 | (a) Give the eligibility criteria, and the sources and methods of selection of participants <br> Done -Brief description- |
| :--- | :---: | :--- |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect <br> modifiers. Give diagnostic criteria, if applicable <br> Done when relevant. |
| Data sources/ <br> measurement | $8^{*}$ | For each variable of interest, give sources of data and details of methods of assessment <br> (measurement). Describe comparability of assessment methods if there is more than <br> one group <br> Done |
| Bias | 9 | Describe any efforts to address potential sources of bias <br> Not applicable Limitations covered later |
| Study size | 10 | Explain how the study size was arrived at <br> Referred to survey methodology papers |
| Quantitative | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe <br> which groupings were chosen and why <br> Done |
| Statistical methods | 12 | (a) |
| Done- Confounding not considered in this type of analysis |  |  |

(b) Describe any methods used to examine subgroups and interactions
Not applicable
(c) Explain how missing data were addressed
Not applicable
(d) $\quad$ describe analytical methods taking account of sampling strategy
Done
(e) Describe any sensitivity analyses

| Results |  |  |
| :---: | :---: | :---: |
| Participants | 13* | (a) Report numbers of individuals at each stage of study-eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed <br> Numbers provided in tables |
|  |  | (b) <br> Give reasons for <br> non-participation at each stage <br> Not relevant for this study. Provided in the original survey method papers |
|  |  | (c) <br> Consider use of a flow diagram |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders <br> Not relevant for this study. Provided in the original survey method papers |
|  |  | (b) Indicate number of participants with missing data for each variable of interest Numbers provided in tables |
| Outcome data | 15* | Report numbers of outcome events or summary measures Numbers provided in tables |
| Main results | 16 | (a) <br> Give unadjusted <br> estimates and, if applicable, confounder-adjusted estimates and their precision (eg, $95 \%$ confidence interval). Make clear which confounders were adjusted for and why they were included <br> Not applicable |
|  |  | (b) Report category <br> boundaries when continuous variables were categorized <br> Standard error provided to simplify tables. Would be too cumbersome to add all CI |
|  |  | (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period |
| Other analyses | 17 | Report other analyses done-eg analyses of subgroups and interactions, and sensitivity analyses <br> Not applicable |
| Discussion |  |  |
| Key results | 18 | Summarise key results with reference to study objectives <br> Done |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias <br> Done |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence Done |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results <br> Done-Since these are national representative populations surveys |
| Other information |  |  |


| Funding $22 \quad$Give the source of funding and the role of the funders for the present study and, if <br> applicable, for the original study on which the present article is based <br> Done |
| :--- | :--- |


[^0]:    *Bp TRU ${ }^{\text {TM }}$ BP-100 used during home visits for respondents who were unable or unwilling to go at the mobile clinic.
    ${ }^{\dagger}$ US NHANES survey protocol: After resting quietly in a sitting position for 5 minutes, three consecutive blood pressure readings were obtained. If a blood pressure measurement was interrupted or incomplete, a fourth attempt could be made.

[^1]:    *Bp TRUTM BP-100 used during home visits for respondents who were unable or unwilling to go at the mobile clinic.
    † US NHANES survey protocol: After resting quietly in a sitting position for 5 minutes, three consecutive blood pressure readings were obtained. If a blood pressure measurement was interrupted or incomplete, a fourth attempt could be made. All valid blood pressure readings excluding pregnant women.

[^2]:    *Bp TRUTM BP-100 used during home visits for respondents who were unable or unwilling to go at the mobile clinic.
    † US NHANES survey protocol: After resting quietly in a sitting position for 5 minutes, three consecutive blood pressure readings were obtained. If a blood pressure measurement was interrupted or incomplete, a fourth attempt could be made.
    All valid blood pressure readings excluding pregnant women.

