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Trends in blood pressure and hypertension detection, treatment and control 1980–2009: The Minnesota Heart Survey

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Abstract

Background—Hypertension is common and treatable but detection and control remain a major health challenge. This study sought to determine population trends in blood pressure and in the control of hypertension in the Minneapolis/St. Paul area (2010 population: 2.85 million) from 1980–2009.

Methods and Results—Surveys of risk factors were carried out every five years among randomly selected adults aged 25–74.

Data on hypertension knowledge and use of medications were collected by interview. Blood pressure was measured using standardized methods with hypertension defined as blood pressure ≥140 and/or 90 mmHg or controlled (<140 and/or 90mmHg) on medications.

Six surveys included 11,192 men and 12,795 women. Mean systolic blood pressure (SBP) fell from 124.9 mmHg in 1980–82 to 121.1 mmHg in 2007–09 for men (p<.0001) and for women from 120.1 mmHg to 114.7 mmHg (p<.0001). Similar trends for diastolic blood pressure wereobserved. Adults with uncontrolled blood pressure (≥140 and/or 90 mmHg) with or without medication fell from 20.3% to 5.8% (p<.001) for men and 13.1% to 2.7% (p<.0001) for women. Anti-hypertensive medication use rose to over 50% among all adults aged 55–74. Men (66%) and women (72%) with hypertension were treated and controlled by 2007–09. A majority of the decline in mean population blood pressure was the result of control with aggressive use of anti-hypertensive drugs. Stroke mortality in this population fell in parallel.

Conclusions—Hypertension detection and control in this community is among the highest observed in a US population and already exceeds Health People 2020 goals.

Keywords

Hypertension; Blood Pressure; Stroke; Epidemiology

INTRODUCTION

Hypertension is common in the United States afflicting over 76 million adults aged 20 and greater.[1] It is more prevalent among certain age, gender, race and ethnic groups but afflicts all population segments. Hypertension is associated with coronary heart disease, stroke, heart failure, kidney failure and other chronic conditions.[1,2] Treatments to control hypertension significantly reduce these diseases.[2] As a result, guidelines for the detection,

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DISCLOSURES
None

treatment and control of hypertension have been advocated for over three decades.[3] The result is improved treatment and control associated with declining cardiovascular disease rates.[4] Yet, hypertension is undiagnosed, untreated and uncontrolled in many instances. The most recent national recommendations in Healthy People 2020 continue to emphasize the need for enhanced prevention and hypertension control strategies.[5]

The Minnesota Heart Survey (MHS) is a population-based study of trends in cardiovascular risk factors, morbidity and mortality in a large urban area.[6] At regular intervals, cardiovascular risk factors, including blood pressure, are measured in a sample of adults randomly selected from the population. This report examines trends in population blood pressure and hypertension detection, treatment and control from 1980–2009.

METHODS

The MHS performed cross-sectional risk factor and health behavior surveys on non-institutionalized resident adults aged 25–74 years in the seven-county Minneapolis/St. Paul (MSP) metropolitan area (2010 Census, 2.85 million). Surveys were conducted in: 1980–82, 1985–87, 1990–92, 1995–97, 2000–02, 2007–09. The MSP population is predominantly white and has slightly higher levels of education and employment than the United States population. MHS sampling is designed to obtain a random sample of the target population. These methods have been described in detail elsewhere.[7,8] In brief, a two-stage cluster design was created from census maps. The seven-county metropolitan area was divided into 704 clusters of approximately 1,000 households each. Forty clusters were randomly selected and used for each survey with a sample of households randomly selected from within each cluster. The sampling fraction (5–10%) varied by resources. The census maps were updated before each survey to account for new housing developments and sampling was adjusted accordingly. In 1995, four clusters were added to represent new population growth and in 2007, three more clusters were added for a total of 47. Once a house was selected, it was removed from sampling in future surveys. There were small differences in the sampling methodology between surveys, which are previously described.[9]

After an introductory letter, selected households were visited by a trained interviewer who performed a household enumeration with those eligible selected for the survey.

Data collection was performed in two stages. An initial home interview solicited information on history of hypertension, medication use for hypertension, and other health indicators. A visit to a survey center at a nearby clinic, public building or at a university clinical center followed. At that site, further information was obtained including direct measurement of blood pressure, body height and weight. If an individual was unable or unwilling to come to the survey center, a second home visit could be scheduled for the additional measurements.

Blood pressure was measured with a random zero (RZ) sphygmomanometer (Hawksley, West Sussex, United Kingdom) from 1980–97 by technicians trained according to the method of Prineas using an appropriate size cuff.[10] After five minutes seated rest, two blood pressure measures were taken one minute apart with the right arm at the level of the heart. The systolic blood pressure (SBP) and fifth phase diastolic blood pressure (DBP) were recorded and the average of these two measures used for these analyses. Room temperature, time of day, pulse rate, recent smoking and other characteristics known to affect blood pressure were also recorded as potential adjustment factors. Quality of blood pressure measures was evaluated with periodic calibration of the sphygmomanometer, observation of technician procedures, and the surveillance of blood pressure distribution values obtained by each technician.

During the 1995–97 survey, a study comparing the random zero sphygmomanometer with the Dinamap (GE Medical Systems Information Technologies, Inc., Milwaukee, WI) automated device was performed. All clinic subjects' blood pressure levels were measured with both the RZ device and the Dinamap monitor. The order of use of the device for each pair of measurements was random. In the 1995–97 survey period (n=4285), mean SBP was 118.70 ± 16.0 mmHg using the RZ and was 120.06 ± 18.3 mmHg using the Dinamap. RZ DBP was 72.5 ± 10.23 mmHg and 70.1 ± 10.10 mmHg for the Dinamap. In 2000 only the Dinamap was used. In order to assess time trends in blood pressure the calibration of the Dinamap to the RZ was evaluated by regressing the average RZ measure on the average Dinamap measure, yielding the following equations: estimated RZ SBP = 28.1240 + 0.7544*DINAMAP SBP, $r^2 = 0.75$ and estimated RZ DBP = 21.7225 + 0.7246*DINAMAP DBP, $r^2 = 0.51$. The observed RZ SBP was lower than the DINAMAP SBP below a blood pressure of 115.5 mmHg and higher above that value. Similarly, the observed RZ DBP was lower than the DINAMAP DBP below a blood pressure of 79.5 mmHg and higher above that value. Reported values were adjusted based on these findings.

The RZ device is known to read slightly, but systematically, lower than the standard sphygmomanometer. We previously published a comparability study and the RZ values were adjusted to the standard sphygmomanometer for this presentation.[11]

Participation rates for a fully completed survey ranged from 56–69% of the selected samples with declining rates over time. More extensive data are available for the entire sample than in those who participated in the home interview alone. Clinic respondents were slightly more likely than non-respondents to be married, employed, better educated and non-smokers. But, they did not differ at the home interview in reporting a history of hypertension.

Mortality trend data for stroke in the Minneapolis/St. Paul metropolitan area as accessed through the Minnesota Department of Health official records.[12] It was age-adjusted to the 2000 Census data.

Statistical analysis

All analyses were sex-specific to illuminate the male/female differences in blood pressure level detection and treatment. General linear modeling techniques using SAS PROC GLM were used to estimate and test for differences among age-specific mean levels of SBP and DBP, and body mass index (BMI). The cluster design was included by adding the neighborhood clusters as a random effect. This allowed computation of an unbiased estimate of the variance of the sample means, resulting in an inflation of the variance by approximately 5%. Age-adjusted prevalences of hypertension (using blood pressure cut-points: ≥140 and/or 90 mmHg and/or medication use) in the six surveys were analyzed by logistic regression with neighborhood cluster as a random effect, using SAS PROC GLIMMIX. Orthogonal polynomials were used to test linear functions simultaneously. Hypertensive patients at each survey were further classified into four mutually exclusive groups: aware, treated, and controlled; aware, treated, and uncontrolled; aware, untreated, and uncontrolled; and unaware.

SAS software was used for all analyses (SAS Institute Inc, Version 8.2. Cary, NC: SAS Institute Inc).

This study was approved by the Institution Review Board of the University of Minnesota and all participants signed an informed consent.

RESULTS

A total of 23,978 adults aged 25–74 participated in the six surveys (11,192 men and 12,795 women). The average age of the population rose over time. As shown in Tables 1 and 2, there were significant trends in SBP and DBP over the 30 years of the study. Men fell from an average 124.9 mmHg to 121.2 mmHg, and women an average 120.1 mmHg to 114.7 mmHg significant linear downward trends (p<.0001). DBP also demonstrated a downward trend for both men and women between 1980–82 and 2007–09. Although the magnitude of DBP fall was less, significant declines were also observed. Average BMI, a measure of obesity, rose over time leveling only in the last survey.

Most striking is the dramatic decline in individuals with recorded blood pressures ≥140 and/or 90 mmHg with or without medications. The numbers trended steadily downward from 1980–82 to 2007–09 falling from 22.1% to 6.8% (p<.0001) for men and 17.9% to 4.0% (p<.0001) for women. In addition, individuals with blood pressures of ≥160 and/or 100 mmHg were rare by the 2007–09 survey (<0.2%) (not shown).

The details for treatment categories are shown in Figure 1. Using the standard categories of aware, treated, controlled and unaware, we note dramatic changes, particularly in the last two surveys. Those who are aware, treated with medications and controlled using a definition of <140 and <90mmHg are dramatically increased and comprise 66% of men and 72% of women with reported hypertension in the 2007–09 survey. At the same time, those who are aware, treated and uncontrolled or unaware are shrinking proportions of the hypertensive population.

In Tables 1 and 2, we observe the trends in SBP and DBP among normotensives, treated hypertensives and untreated hypertensives. These subcategories reveal the source of much of the decline in overall SBP in the population. Normotensives' blood pressures have remained relatively stable over time, without evidence of trends. However, treated hypertensives have dramatically improved over time with a decline in mean SBP for hypertensive men from 135.6 mmHg in 1980–82 to 125.2 mmHg in 2007–09 (p<.0001). For women, there are similar improvements in the control of hypertensives with an average SBP level in 1980–82 of 137.8 mmHg to 123.5 mmHg in 2007–09. Untreated hypertensives have no trend in SBP, although they decreased substantially in proportion of the population. DBP showed similar, although more modest trends, with treated hypertensives playing the largest role in the decline in overall population blood pressure. It is clear from these data that hypertension is commonly detected and aggressively treated to recommended targets.

Table 3 describes antihypertensive drug use trends by age and sex. The use of anti-hypertensive medications steadily rises with age and in the highest age categories (55–74 years) an average of 50% of all free living adults are now on anti-hypertensive medication. Again, there is a steady increase from the 1980s. The effects of high levels of antihypertensive medication use, particularly in older adults age 55–74, are observed in the age specific SBP trends (Figure 2). The trends in prevalence of treatment and more effective treatment are of a magnitude to affect the populations' SBP.

Mortality trends for cerebrovascular disease (stroke) from 1990–2009 in the state of Minnesota parallel these blood pressure changes (Figure 3).[12] The overall trends for both men and women are downward. However, the effect is particularly dramatic since the year 2000. From 1990–1999, the average decline in age-adjusted stroke mortality was 1.0%/year while in 2000–2009 it was 3.5%/year.

DISCUSSION

The improved detection, treatment and control of hypertension are among the more important health achievements of the past 50 years.[4] Substantial evidence from laboratory, epidemiologic and clinical trial data followed by vigorous public and professional education campaigns from the National High Blood Pressure Education Program, industry and many voluntary organizations led to major changes in clinical practice.[13,14] The Joint National Committee (JNC) on Prevention, Detection, Evaluation and Treatment of High Blood Pressure, now in its 7th edition, periodically summarizes the scientific data and makes public recommendations.[2] Medications to treat hypertension are among the most commonly prescribed and sold.[15] Despite all this progress, many cases are undetected and uncontrolled, with certain groups in the population lagging in their access to and utilization of successful treatments.[16] Some authorities have even speculated that the attainment of a goal blood pressure of 140/90 or less in 50% of hypertensives may be “the best we can do”.[17]

Data from the MHS provide population-based distributions of blood pressure and hypertension and their trends in a large urban population. Consistent sampling from a fixed geographic area and careful measurement methods allow valid comparisons over time. Blood pressure and hypertension control have been an area of particular interest in Minnesota, dating back to a 1973–74 survey[18] and more recently an evaluation of trends from 1980–2002.[19]

Among the more interesting findings in this study are the continuous decline of mean SBP and DBP in the population and an apparent source of those declines. Mean blood pressures among ‘normotensives’, or those with blood pressure less than 140/90, have remained stable from the 1980–82 survey to 2007–09. Those with untreated hypertension also have stable mean blood pressures. However, large differences in mean SBP and DBP over time are found among treated hypertensives. Their mean SBP has fallen, on average, more than 10 mmHg in men and 14 mmHg in women. Similar differences are observed for treated DBP, which fell more than 6 mmHg for men and 8 mmHg for women. This is coupled with an increasing proportion of hypertensives detected and under treatment. Effective treatment and the total of treated hypertensives largely accounts for the observed fall in mean blood pressure in the population. Approximately 50% of the general population age 55–74 reported taking antihypertensive drugs.

The summation of these findings is reflected in the dramatic increases in the detection and treatment of hypertension over this period. Approximately 70% of men and women in this population sample are aware, treated and controlled for this condition in 2007–09. Declining numbers are unaware, untreated or inadequately treated. This trend, first noted in 2000–2002, has accelerated despite rising levels of overweight and obesity in this population.

The national picture is seen from the National Health & Nutrition Examination Survey (NHANES) that examined hypertension trends from 1988–2008 among adults aged 18 years and greater.[20] The age window does not directly overlap with MHS (age 25–74 years). Mean SBP in NHANES did not change significantly while DBP fell in the general population over the 20 years of observation. Prevalence of hypertension increased from 1988–2000 but remained flat thereafter. Those with hypertension who were aware of, treated and controlled rose from 27.3% in 1988 to 50.1% in 2007–08. Most of that change was in the second decade of observation. Mean SBP among hypertensives both treated and untreated was 135.2 mmHg in the national sample compared to 127.8 mmHg in MHS for the most recent surveys.

Minnesota data demonstrate significantly better current levels of treatment and control with lower average blood pressures among treated hypertensives than the national NHANES

data. Systematic difference in measurement methods between NHANES and MHS. NHANES utilized the standard sphygmanometer with a blood pressure measured by a health professional and MHS utilized the random zero sphygmanometer or an automated method adjusted to the standard sphygmanometer. NHANES takes three blood pressure measurements in most individuals and uses the mean of the last two measures "when they are available".[20] MHS utilizes the mean of the first and second measures. It is well recognized that the first measured blood pressure is usually the highest value with declines in the second and subsequent measurement.[21] With this difference in methods, one would anticipate that MHS values would be higher as the first MHS measurement is always included in the mean. However, the values are actually lower suggesting Minnesota blood pressure levels, as well as treatment levels, are significantly better than the national data.

Minnesota has among the lowest cardiovascular disease rates in the United States.[22] A previous comparison to NHANES suggests that this is due, in part, to lower mean risk factor levels including smoking rates, hypertension, high cholesterol and obesity.[22] The rates of stroke mortality in Minnesota are partially confirmatory of the greater level of control of hypertension, particularly true in the last decade.[12]

The rates of hypertension detection and control observed in MHS exceed those proposed as goals in Healthy People 2020.[5] The 2020 goal for the American population is 61.2% of the population aware of hypertension and, treated and controlled (ATC). Despite the suggestion that moving the population to a figure above 50% ATC will be difficult,[17] these targets seem very achievable based on the Minnesota experience. It is already attained in studies in Canada and Northern Sweden.[23,24]

The reasons for the quality of hypertension care is speculative. Minnesota has among the highest levels of health insurance among its citizens and has a well-developed healthcare system.[25] These factors, along with greater levels of high school and college education, greater family incomes and fewer people in poverty than the national figures, may contribute to these positive health outcomes.[26]

There are several limitations to this study. Among them are the participation rates in a survey of the general population. Although similar to NHANES, it is possible that those who are non-responders differ in important ways. The two-stage nature of the MHS survey, a home interview followed by a clinic measurement, makes it possible to look at characteristics such as a history of hypertension. Clinic respondents were more likely to be married, employed, better educated and non-smokers. However, a history of hypertension did not differentiate clinic participation from the home interview. These factors also stayed constant, on average, over the years of the study.

Although Minnesota is increasingly diverse, the survey population is mainly Caucasian. In recent years, a larger number of Hispanics, Southeast Asians and East Africans became part of the Minneapolis/St. Paul metropolitan area and were sampled by MHS methods. In the most recent survey (2007–09), 10% of the participants aged 25–74 were non-white.

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Dr. Russell Luepker had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Hypertension is common in the United States afflicting over 76 million adults aged 25 and greater. Treatment is well established reducing cardiovascular complications of hypertension, particularly stroke. In a large metropolitan area, hypertension, detection and control has been a goal for many years. The results of this sustained focus is shown in this paper where approximately 70% of hypertensives in the adult population are aware, treated and controlled to recommended levels. This may be partly due to higher rates of insurance, education and income in the state of Minnesota. However, it also points to quality healthcare systems who have targeted high blood pressure as an important goal for cardiovascular disease prevention. With this combination of factors, it is possible to have high levels of blood pressure control and resulting declines in stroke deaths

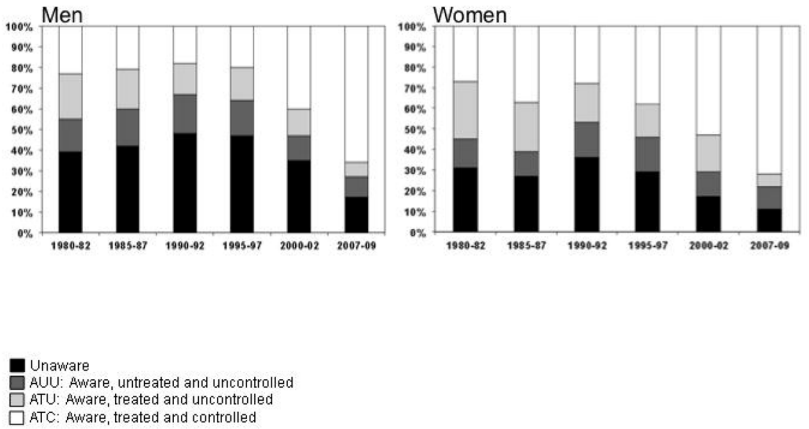

Figure 1.
Trends in detection, treatment and control of hypertension from 1980–82 to 2007–09 for men and women.

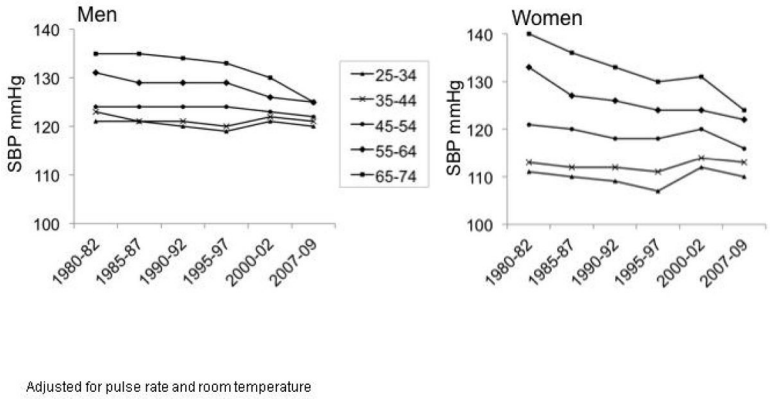

Figure 2.
Systolic blood pressure (mmHg) by sex and age decade.

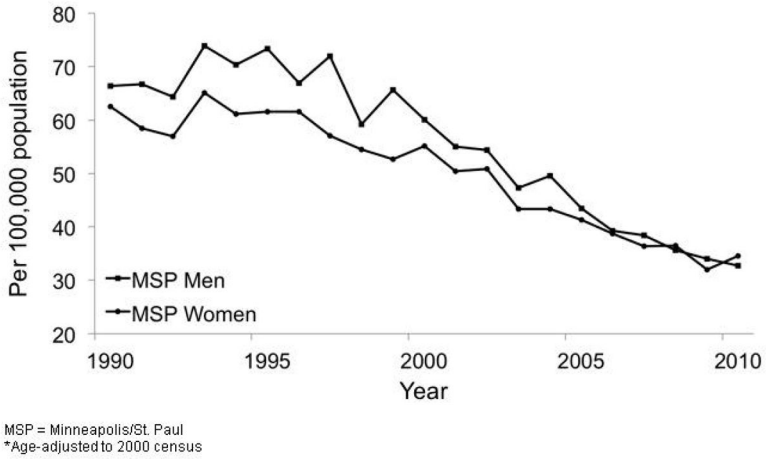

Figure 3.
Age-adjusted mortality for cerebrovascular disease 1990–2009. Source: Minnesota Department of Health[12]

Table 1

Age, Systolic Blood Pressure (SBP) (mmHg), and Body Mass Index (BMI) Trends

	1980–82		1985–87		1990–92		1995–97		2000–02		2007–2009		Trends P=
Men	**N=**	**Mean±SE**	**N=**	**Mean±SE**	**N=**	**Mean±SE**	**N=**	**Mean±SE**	**N=**	**Mean±SE**	**N=**	**Mean±SE**	**Linear trend** *
Age	1238	42.6±0.6	2212	43.8±0.6	2381	44.3±0.5	2605	46.4±0.5	1358	46.7±0.6	1398	49.4±0.6	<0.0001
SBP	1238	124.9±0.5	2212	124.4±0.4	2381	124.1±0.4	2605	123.2±0.4	1358	123.5±0.5	1398	121.1±0.5	<0.0001
Normotensives	897	119.2±0.4	1677	118.8±0.3	1735	118.3±0.3	1935	117.8±0.3	1065	120.6±0.4	1036	119.2±0.4	0.13
Treated HBP	144	135.6±1.4	215	135.5±1.2	232	134.5±1.2	285	134.8±1.1	177	129.8±1.3	304	125.2±1.1	<0.0001
Untreated HBP	197	142.8±0.9	320	144.0±0.7	414	140.5±0.7	385	141.7±0.6	116	141.1±1.1	58	143.6±1.6	0.75
BMI (kg/m^2) **	1238	26.5±0.2	2212	26.9±0.1	2381	27.2±0.1	2605	28.1±0.1	1358	28.4±0.1	1398	29.1±0.2	<0.0001
Women													
Age	1385	43.9±0.6	2417	44.8±0.5	2764	45.3±0.5	2990	45.7±0.5	1540	46.5±0.6	1609	48.5±0.6	<0.0001
SBP	1385	120.1±0.5	2417	118.1±0.4	2764	117.3±0.4	2990	115.7±0.4	1540	118.1±0.5	1609	114.7±0.5	<0.0001
Normotensives	1054	113.3±0.4	1926	112.3±0.3	2263	112.1±0.3	2470	111.2±0.3	1280	114.3±0.4	1318	112.2±0.4	0.89
Treated HBP	177	137.8±1.3	306	135.0±1.0	243	132.3±1.1	280	129.3±1.0	187	131.2±1.3	242	123.5±1.2	<0.0001
Untreated HBP	154	147.5±1.2	185	148.0±1.1	258	143.3±0.9	240	143.8±0.9	73	148.6±1.6	49	144.9±1.9	0.402
BMI (kg/m^2) **	1385	24.9±0.3	2417	26.1±0.2	2764	26.6±0.2	2990	27.3±0.2	1540	28.4±0.3	1609	28.1±0.3	<0.0001

* Linear trend of survey years adjusted for age, room temperature and pulse rate

HBP = ypertension

** Adjusted for age

Table 2

Diastolic Blood Pressure (DBP) (mmHg) Trends

	1980–82		1985–87		1990–92		1995–97		2000–02		2007–2009		Trends P=
Men	**N=**	**Mean±S E**	**N=**	**Mean±S E**	**N=**	**Mean±SE**	**N=**	**Mean±SE**	**N=**	**Mean±SE**	**N=**	**Mean±SE**	**Linear trend** *
DBP	1238	78.1±0.3	2212	76.7±0.3	2381	80.2±0.3	2605	77.9±0.3	1358	78.1±0.3	1398	75.5±0.3	<0.0001
Normotensives	897	74.8±0.3	1677	73.8±0.2	1735	76.7±0.2	1935	74.8±0.2	1065	76.5±0.3	1036	74.3±0.3	0.129
Treated HBP	144	83.7±0.9	215	82.7±0.8	232	83.6±0.7	285	81.2±0.7	177	80.9±0.8	304	77.1±0.7	<0.0001
Untreated HBP	197	88.2±0.7	320	87.7±0.6	414	91.7±0.6	385	91.1±0.6	116	88.9±0.9	58	88.3±1.2	0.62
Women													
DBP	1385	74.0±0.3	2417	72.9±0.3	2764	75.7±0.3	2990	72.8±0.3	1540	73.4±0.3	1609	70.6±0.3	<0.0001
Normotensives	1054	70.9±0.3	1926	70.4±0.2	2263	73.4±0.2	2470	70.8±0.2	1280	72.1±0.3	1318	69.9±0.3	0.39
Treated HBP	177	80.5±0.8	306	79.3±0.6	243	81.7±0.7	280	77.7±0.6	187	77.2±0.7	242	72.1±0.7	<0.0001
Untreated HBP	154	87.7±0.7	185	87.8±0.7	258	89.1±0.6	240	87.3±0.6	73	85.9±1.0	49	83.4±1.3	0.0008

*Linear trend of survey years adjusted for age, room temperature and pulse rate

HBP = Hypertension

Table 3

Antihypertensive Drug Use Trends by Age and Sex (% Population), Age-adjusted

	1980–82		1985–87		1990–92		1995–97		2000–02		2007–09	
Age	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**
25–34	0	0	0	0	0.3	0	2.4	0	0.7	2.4	6.7	3.2
35–44	0	0	0.9	1.1	1.5	0.6	2.4	1.3	6.3	4.4	12.7	9.7
45–54	1.8	1.7	4.9	3.1	5.4	3.7	9.1	5.5	11.8	15.4	35.2	24.4
55–64	7.5	5.3	8.1	10.5	10.0	10.3	20.9	19.5	30.3	28.9	52.1	45.5
65–74	14.8	16.6	18.5	24.7	24.8	23.9	28.5	31.0	41.1	41.5	58.9	46.9