Seasonal variations in home and ambulatory blood pressure in the PAMELA population

Roberto Sega[a,b], Giancarlo Cesana[a], Michele Bombelli[b], Guido Grassi[b,c], Maria Luisa Stella[c], Alberto Zanchetti[c] and Giuseppe Mancia[b,c]

Objective Clinic blood pressure values are known to change according to seasonal influences. We therefore examined home and 24 h ambulatory blood pressure values to determine whether these measurements are also affected by the seasons.

Design and methods In 2051 subjects of the Pressione Arteriose Monitorate E Loro Associazioni (PAMELA) study, we measured clinic (sphygmomanometric measurements), home (semi-automatic device) and ambulatory (Spacelabs 90207) systolic blood pressure, diastolic blood pressure and heart rate. Because the overall sample was evenly distributed over each month (except August), we were able to make a cross-sectional determination of whether the values differed between seasons. The corresponding heart rates were also evaluated.

Results As expected, summer was associated with the lowest clinic blood pressure and winter with the highest, and this was the case also for home and 24 h average blood pressure, although seasonal differences in the latter were less pronounced. Seasonal clinic, home and ambulatory blood pressure patterns were similar for normotensive subjects (n = 1152), untreated hypertensives (n = 540) and treated hypertensives (n = 359). Heart rate values did not differ by season.

Conclusions Seasonal influences on blood pressure are not limited to conventional measurements but characterize daily values as well. These effects are visible in both normal and elevated blood pressure values, regardless of the effect of antihypertensive drugs. This has implications both for the clinician and for studies aimed at evaluating the effects of antihypertensive treatment. *J Hypertens* 1998, 16:1585–1592 © Lippincott Williams & Wilkins

Journal of Hypertension 1998, 16:1585–1592

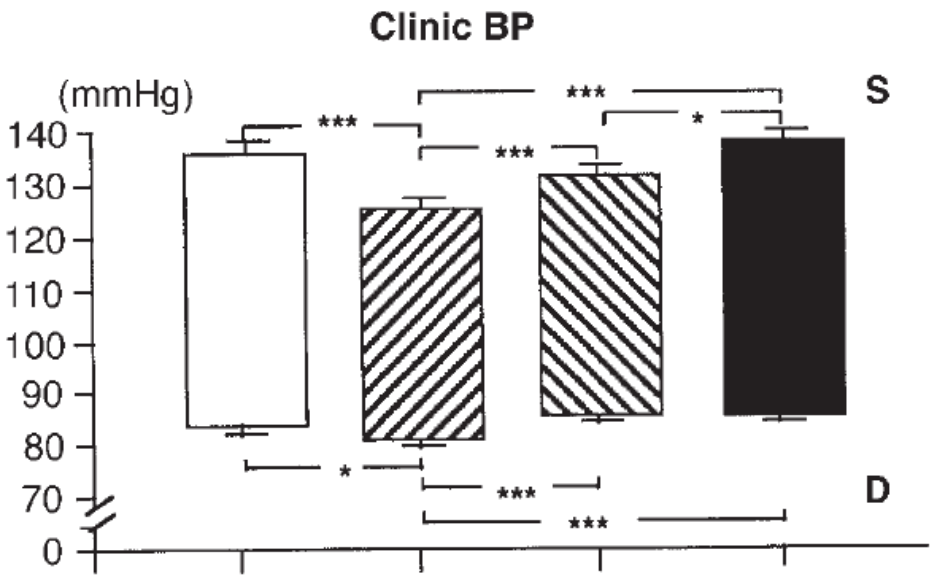
Keywords: clinic blood pressure, home blood pressure, 24 h ambulatory blood pressure, seasons, temperature

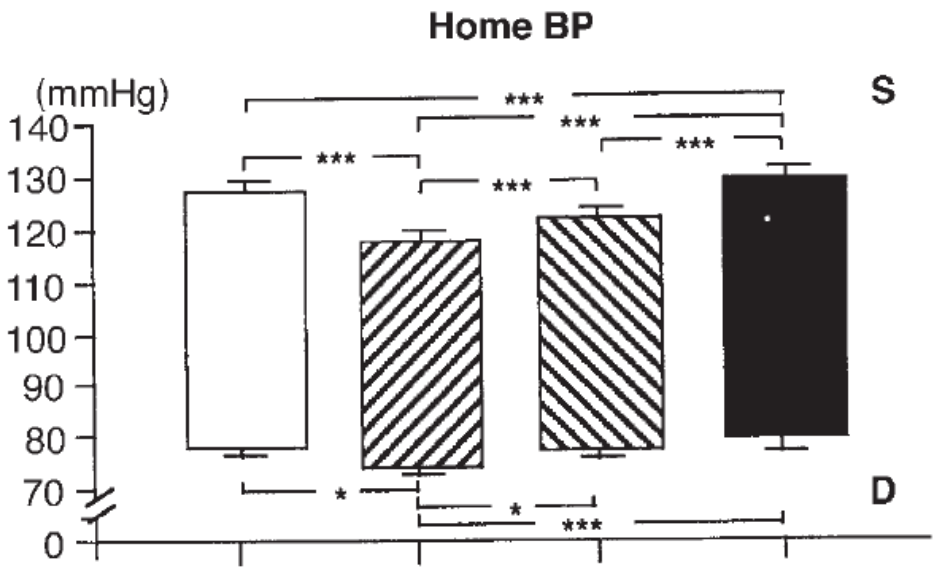
[b]Cattedra di Medicina Interna I, Centro Studi di Patologia Cronico-Degenerativa, Università di Milano, Ospedale S. Gerardo dei Tintori, Monza (MI), [c]Centro di Fisiologia Clinica e Ipertensione, IRCCS Ospedale Maggiore, Milan, and [a]ISTRA, Milan, Italy.

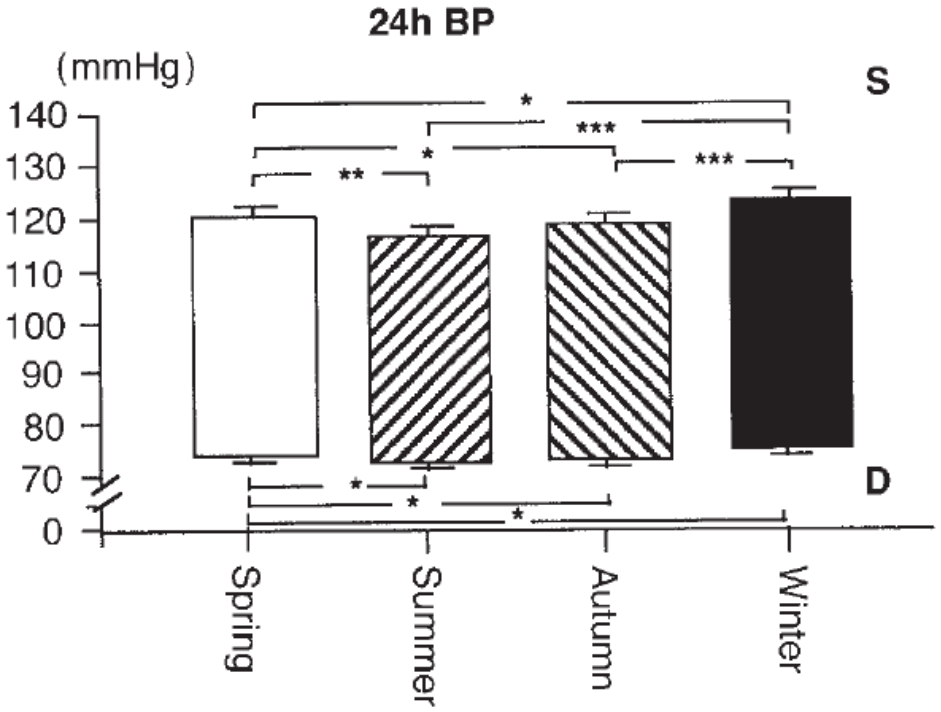
Sponsorship: This study was supported by a research grant from Glaxo Italy, and by the National Research Council, Italy (Progetto FATMA no. 41.115.02280).

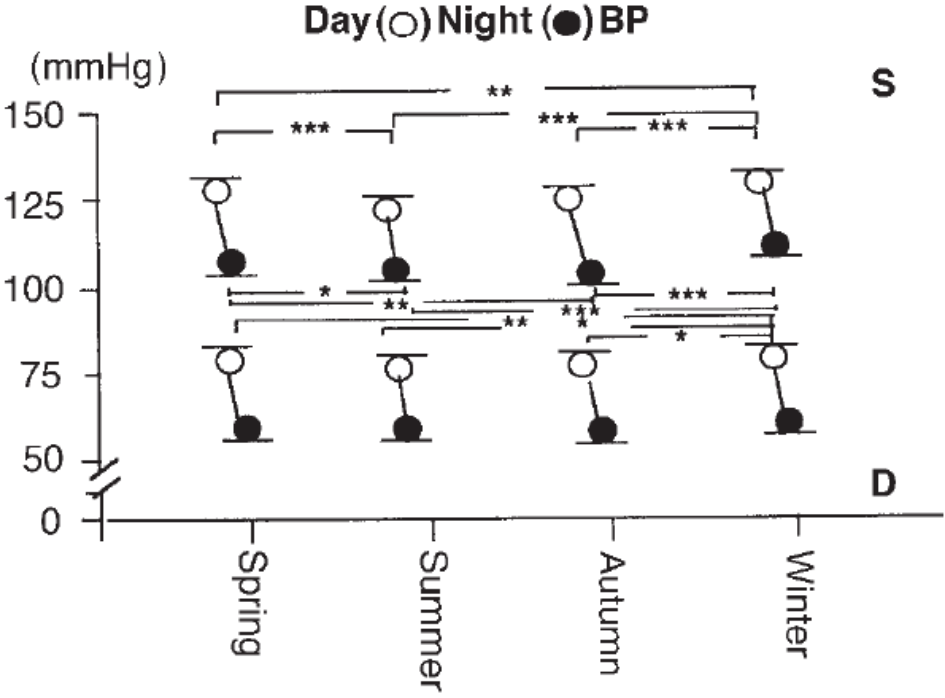
Correspondence and requests for reprints to Professor Giuseppe Mancia, Cattedra di Medicina Interna I, Università di Milano, Ospedale S. Gerardo dei Tintori, Via Donizetti 106, I-20052 Monza (MI), Italy.
Tel: +39 39 233 3357; Fax: +39 39 322 274

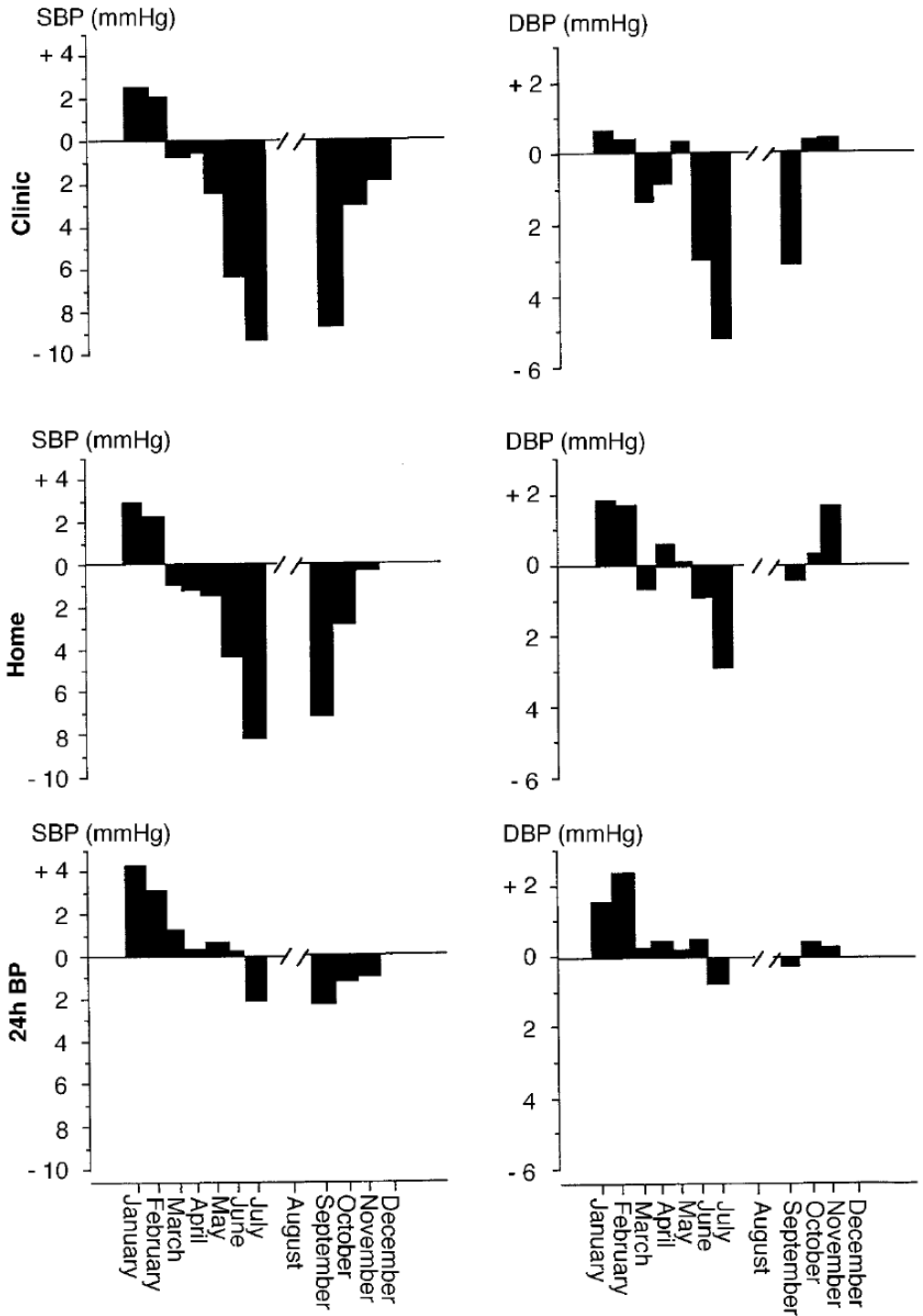
Received 5 March 1998 **Revised** 25 June 1998
Accepted 10 July 1998

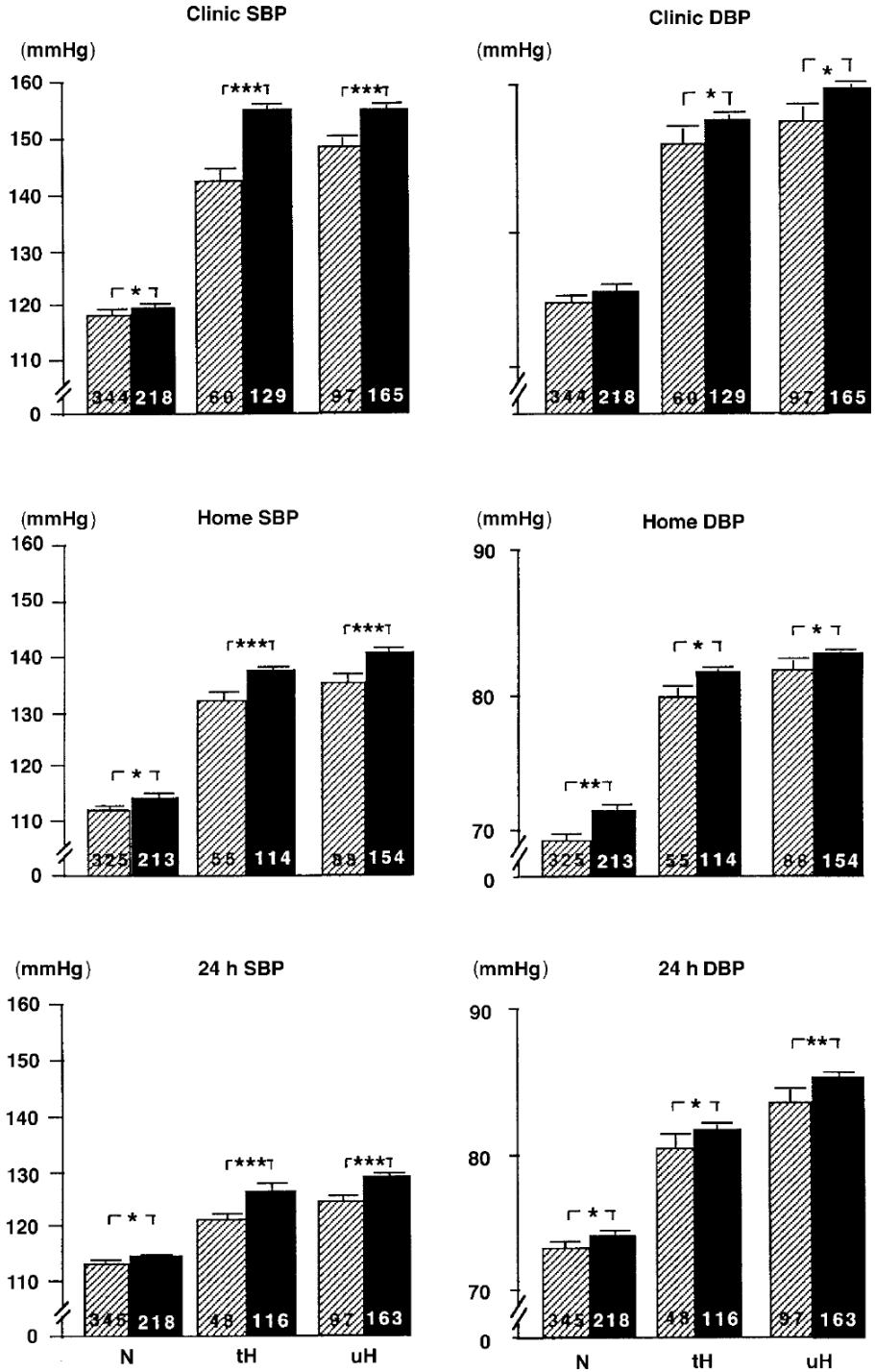

Clinic BP
(mmHg)
S
D
140
130
120
110
100
90
80
70
0


Home BP
(mmHg)
S
D
140
130
120
110
100
90
80
70
0


24h BP
(mmHg)
S
D
140
130
120
110
100
90
80
70
0
Spring
Summer
Autumn
Winter


Day (○) Night (●) BP
(mmHg)
S
D
150
125
100
75
50
0
Spring
Summer
Autumn
Winter


SBP (mmHg)
DBP (mmHg)
Clinic
Home
24h BP
+ 4
2
0
2
4
6
8
- 10
+ 2
0
2
4
- 6
January
February
March
April
May
June
July
August
September
October
November
December


Clinic SBP
(mmHg)
160
150
140
130
120
110
0
*
***
***
344
218
60
129
97
165
Clinic DBP
(mmHg)
*
*
344
218
60
129
97
165
Home SBP
(mmHg)
160
150
140
130
120
110
0
*
***
***
325
213
55
114
88
154
Home DBP
(mmHg)
90
80
70
0
**
*
*
325
213
55
114
88
154
24 h SBP
(mmHg)
160
150
140
130
120
110
0
*
***
***
345
218
48
116
97
163
N
tH
uH
24 h DBP
(mmHg)
90
80
70
0
*
*
**
345
218
48
116
97
163
N
tH
uH

Relationship Between Blood Pressure and Outdoor Temperature in a Large Sample of Elderly Individuals

The Three-City Study

Annick Alpérovitch, MD; Jean-Marc Lacombe, MSc; Olivier Hanon, MD; Jean-François Dartigues, MD; Karen Ritchie, PhD; Pierre Ducimetière, PhD; Christophe Tzourio, MD

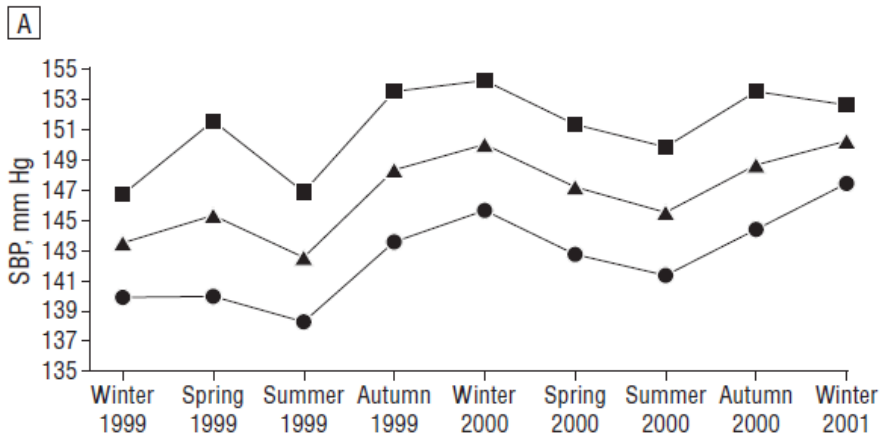
Background: Seasonal variations of blood pressure–related diseases have been described in several populations. However, few studies have examined the seasonal variations of blood pressure in the elderly, a segment of the population particularly exposed to vascular diseases. The association of blood pressure with season and outdoor temperature was examined in 8801 subjects 65 years or older from the Three-City study, a population-based longitudinal study.

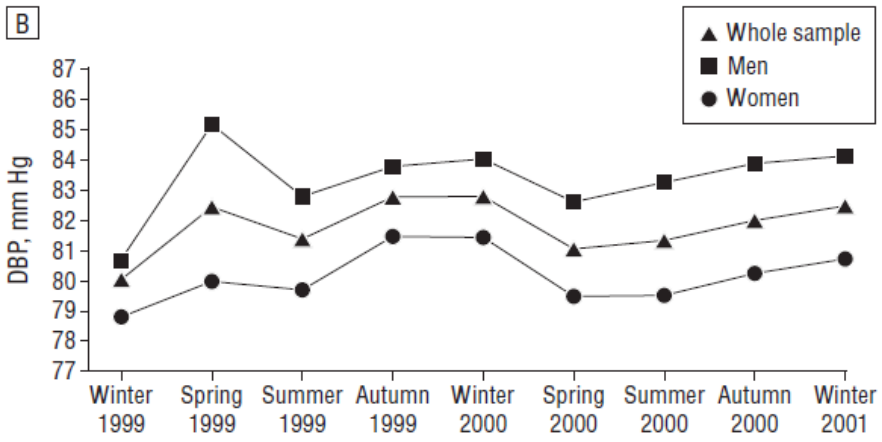
Methods: Blood pressure was measured at baseline and 2-year follow-up examinations. Daily outdoor temperature measured at 11 AM was provided by the local meteorological offices.

Results: Both systolic and diastolic blood pressure values differed significantly across the 4 seasons and across the quintiles of the distribution of outdoor temperature. Systolic blood pressure decreased with increasing temperature, with an 8.0–mm Hg decrease between the lowest (<7.9°C) and the highest (≥21.2°C) temperature quintile. Intraindividual differences in blood pressure between follow-up and baseline examinations were strongly correlated with differences in outdoor temperature. The higher the temperature at follow-up compared with baseline, the greater the decrease in blood pressure. Longitudinal changes in blood pressure according to difference in outdoor temperature were larger in subjects 80 years or older than in younger participants.

Conclusions: Outdoor temperature and blood pressure are strongly correlated in the elderly, especially in those 80 years or older. During periods of extreme temperatures, a careful monitoring of blood pressure and antihypertensive treatment could contribute to reducing the consequences of blood pressure variations in the elderly.

Arch Intern Med. 2009;169(1):75-80


A
SBP, mm Hg
155
153
151
149
147
145
143
141
139
137
135
Winter 1999
Spring 1999
Summer 1999
Autumn 1999
Winter 2000
Spring 2000
Summer 2000
Autumn 2000
Winter 2001

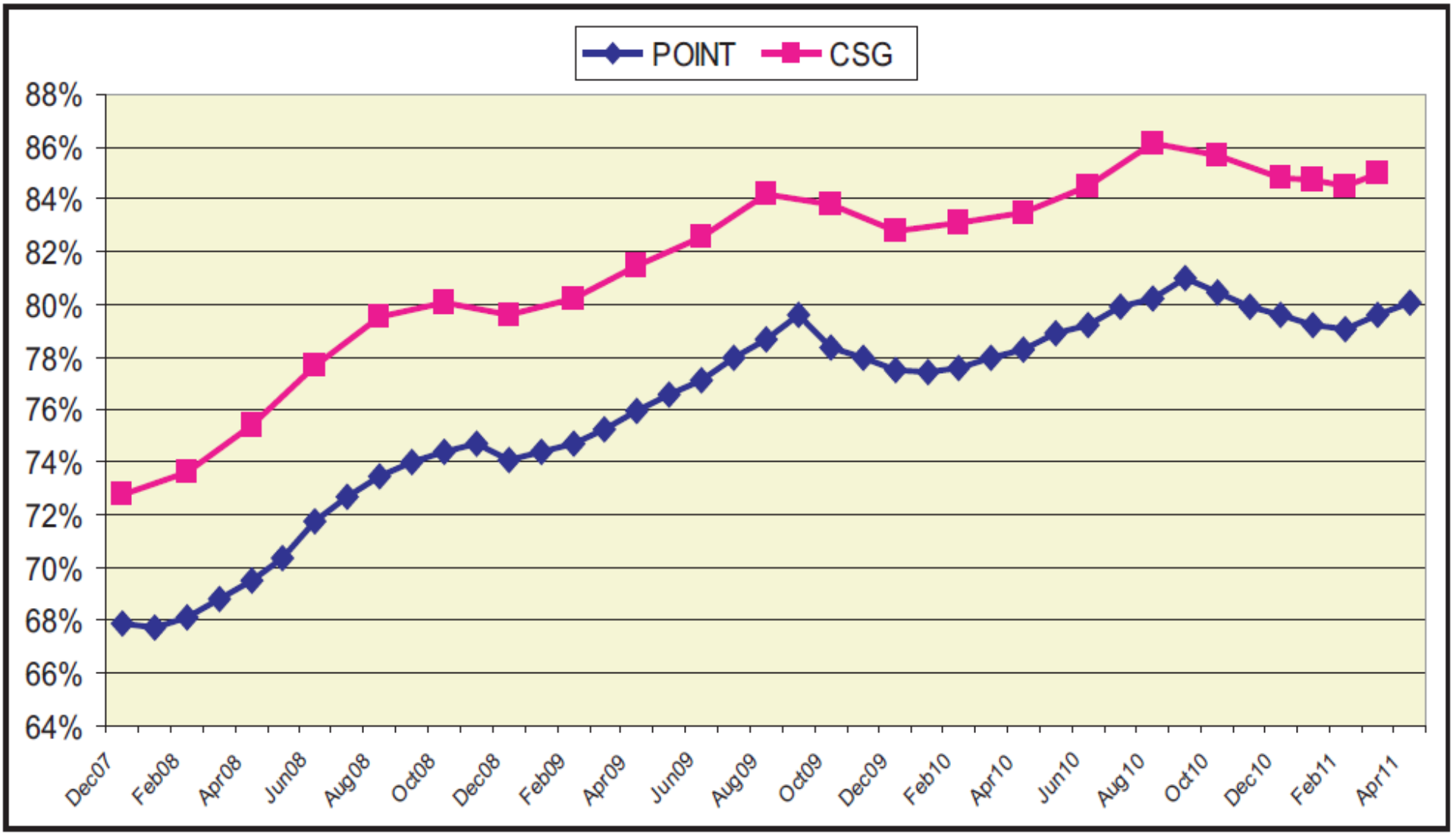

B
DBP, mm Hg
87
86
85
84
83
82
81
80
79
78
77
Whole sample
Men
Women
Winter 1999
Spring 1999
Summer 1999
Autumn 1999
Winter 2000
Spring 2000
Summer 2000
Autumn 2000
Winter 2001

CASE STUDIES IN HYPERTENSION
Joel Handler, MD, Section Editor

Seasonal Variability of Blood Pressure in California

Joel Handler, MD

The Journal of Clinical Hypertension Vol 13 | No 11 | November 2011


POINT
CSG
88%
86%
84%
82%
80%
78%
76%
74%
72%
70%
68%
66%
64%
Dec07
Feb08
Apr08
Jun08
Aug08
Oct08
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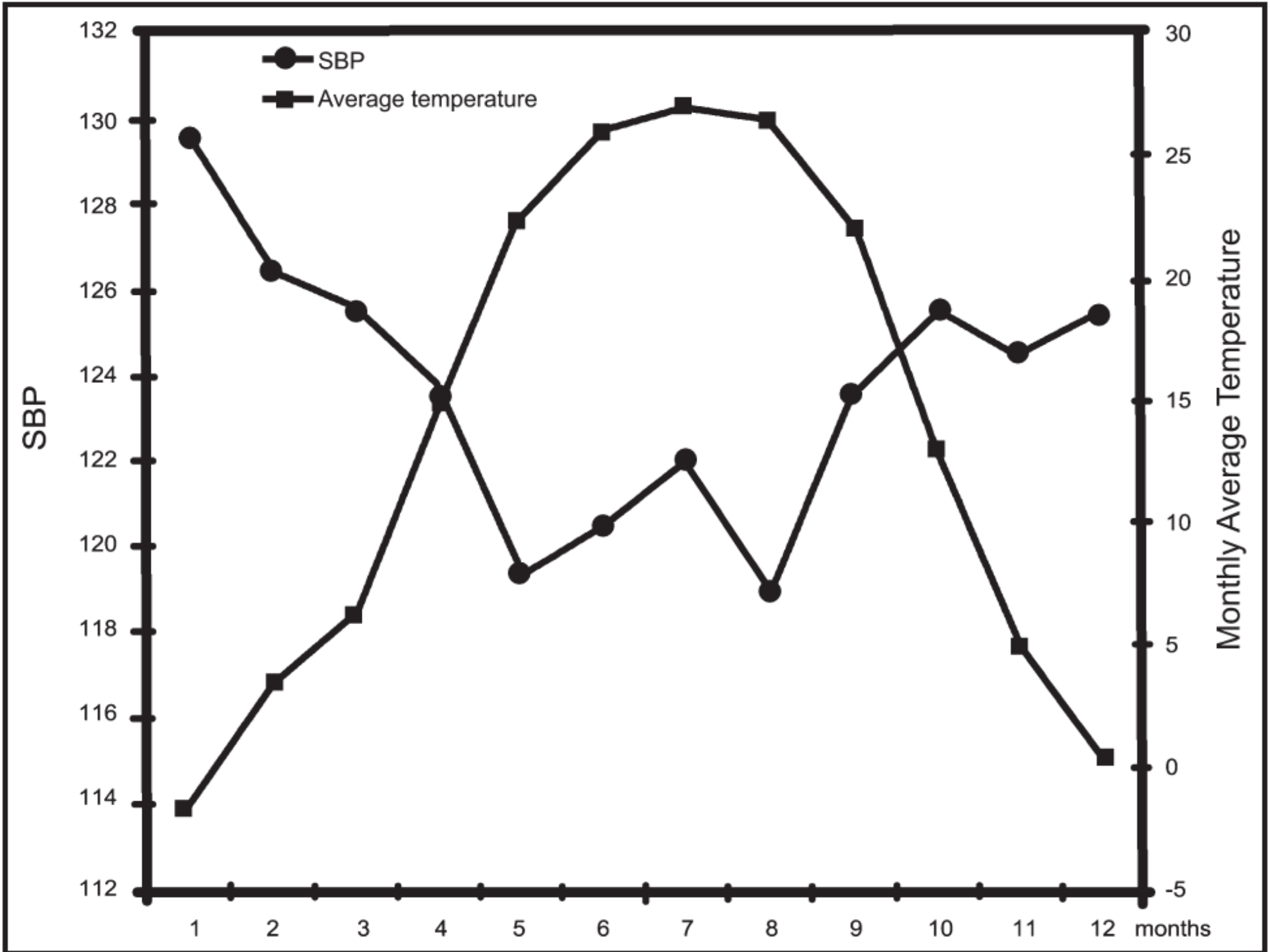
Feb10
Apr10
Jun10
Aug10
Oct10
Dec10
Feb11
Apr11


SBP
Average temperature
SBP
Monthly Average Temperature
132
130
128
126
124
122
120
118
116
114
112
30
25
20
15
10
5
0
-5
1
2
3
4
5
6
7
8
9
10
11
12
months

Blood Pressure Control Among US Veterans

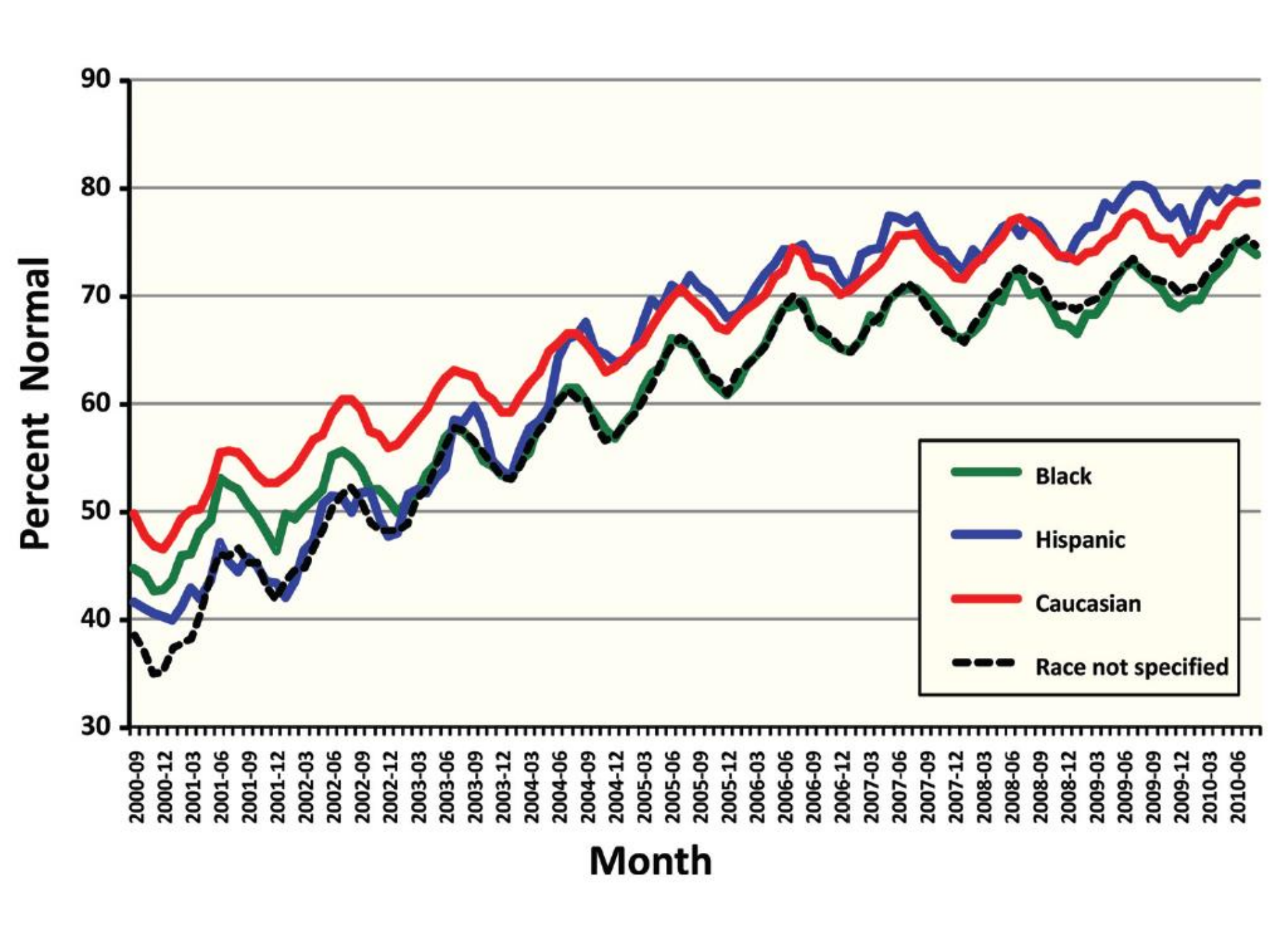
A Large Multiyear Analysis of Blood Pressure Data From the Veterans Administration Health Data Repository

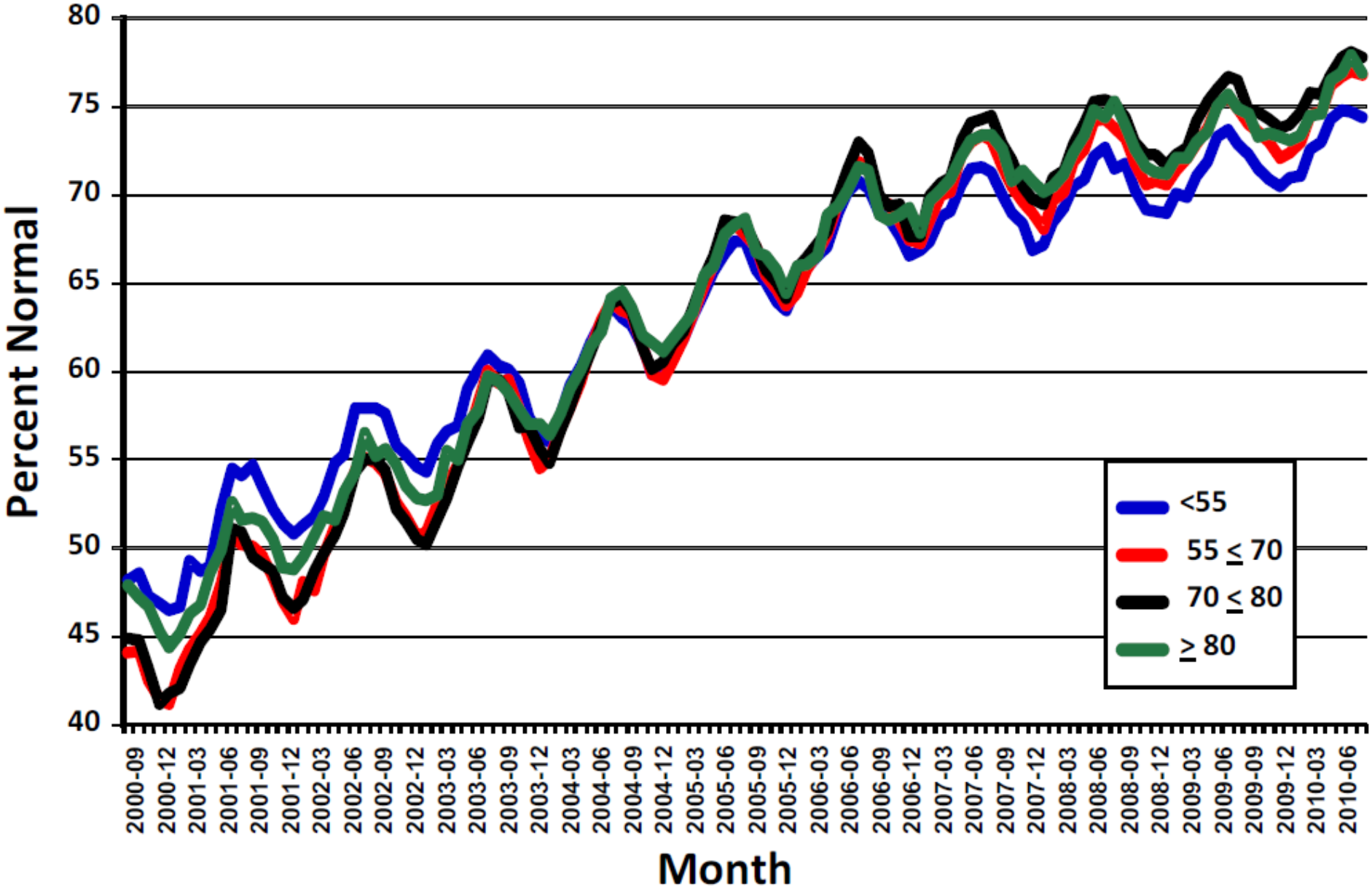
Ross D. Fletcher, MD; Richard L. Amdur, PhD; Robert Kolodner, MD; Chris McManus, MA; Ronald Jones, MSEE; Charles Faselis, MD; Peter Kokkinos, PhD; Steven Singh, MD; Vasilios Papademetriou, MD

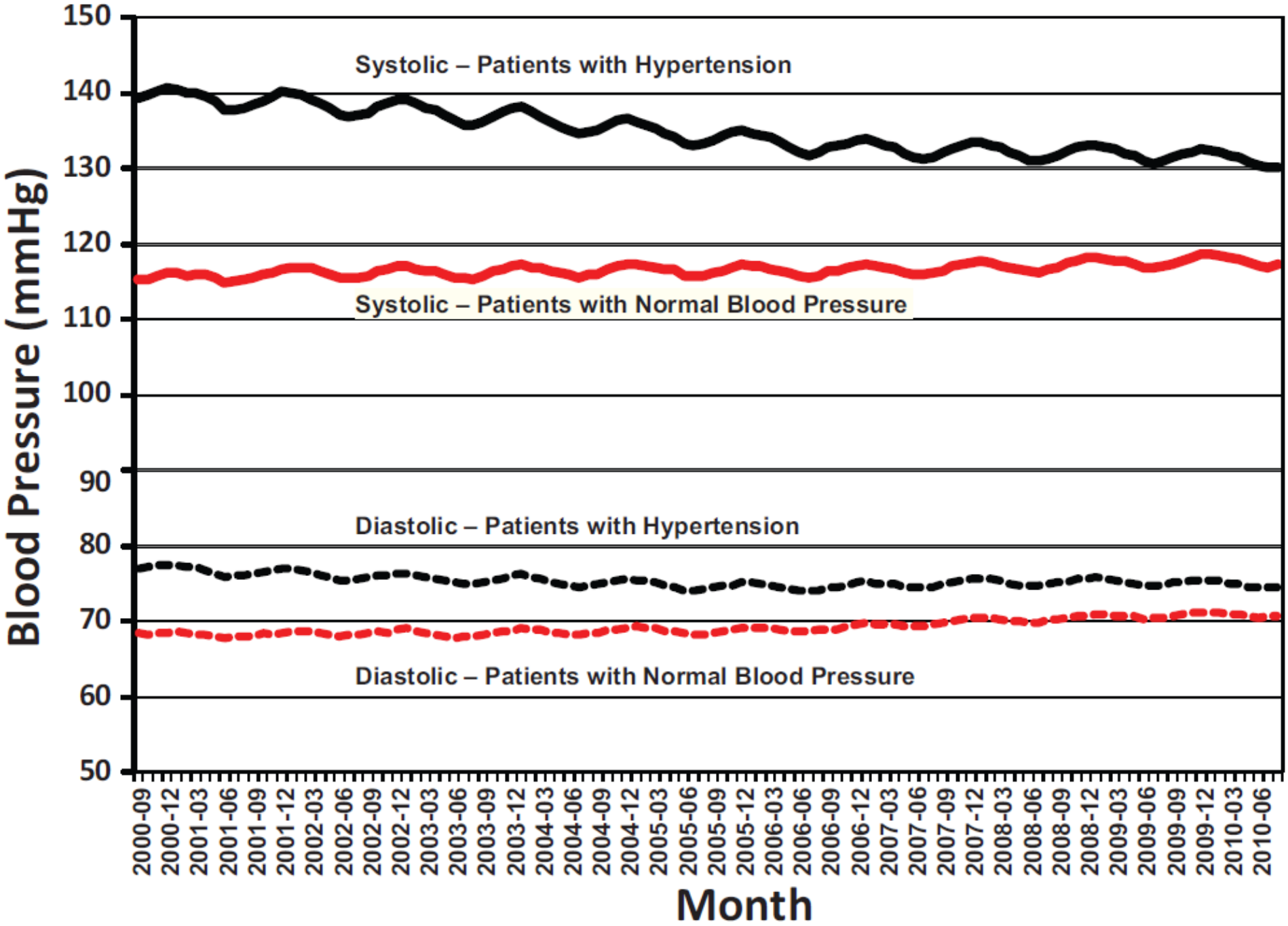
Background—Hypertension treatment and control remain low worldwide. Strategies to improve blood pressure control have been implemented in the United States and around the world for several years. This study was designed to assess improvement in blood pressure control over a 10-year period in a large cohort of patients in the Department of Veterans Affairs.

Methods and Results—A cohort of 582 881 hypertensive patients and 260 924 normotensive individuals treated in 15 Department of Veterans Affairs medical centers between 2000 and 2010 were examined. Strategies used system-wide included blood pressure control as a performance measure, automatic notification to healthcare providers, electronic reminders, and a systematic revisit schedule. The main outcome measure was the percentage of hypertensive patients whose hypertension was controlled and the level of blood pressure each month. In the hypertensive cohort (mean age 62.9±13.4 years, 96.0% male), 52.3% of patients were white, 25.1% were black, and 21.1% were Hispanic. Blood pressure control rates improved from 45.7% in September 2000 to 76.3% in August 2010. Improvements were similar across ethnic, racial, age, and sex groups. Average systolic/diastolic blood pressure decreased from 142.6/77.1 mm Hg in 2000 to 131.2/74.8 mm Hg in 2010, a decrease of 11.3/2.3 mm Hg ($P<0.0001$ for both). Systolic and diastolic blood pressures were lower in summer than in winter, and this trend continued through 2010. On average, control rates increased by 3.0% per year and were 6.8% higher in summer than in winter.

Conclusions—High rates of blood pressure control can be achieved in all age and ethnic groups and in both sexes. **(*Circulation*. 2012;125:2462-2468.)**


Percent Normal
90
80
70
60
50
40
30
Black
Hispanic
Caucasian
Race not specified
2000-09
2000-12
2001-03
2001-06
2001-09
2001-12
2002-03
2002-06
2002-09
2002-12
2003-03
2003-06
2003-09
2003-12
2004-03
2004-06
2004-09
2004-12
2005-03
2005-06
2005-09
2005-12
2006-03
2006-06
2006-09
2006-12
2007-03
2007-06
2007-09
2007-12
2008-03
2008-06
2008-09
2008-12
2009-03
2009-06
2009-09
2009-12
2010-03
2010-06
Month


Percent Normal
80
75
70
65
60
55
50
45
40
<55
55 ≤ 70
70 ≤ 80
≥ 80
2000-09
2000-12
2001-03
2001-06
2001-09
2001-12
2002-03
2002-06
2002-09
2002-12
2003-03
2003-06
2003-09
2003-12
2004-03
2004-06
2004-09
2004-12
2005-03
2005-06
2005-09
2005-12
2006-03
2006-06
2006-09
2006-12
2007-03
2007-06
2007-09
2007-12
2008-03
2008-06
2008-09
2008-12
2009-03
2009-06
2009-09
2009-12
2010-03
2010-06
Month


Systolic – Patients with Hypertension
Systolic – Patients with Normal Blood Pressure
Diastolic – Patients with Hypertension
Diastolic – Patients with Normal Blood Pressure
Blood Pressure (mmHg)
150
140
130
120
110
100
90
80
70
60
50
2000-09
2000-12
2001-03
2001-06
2001-09
2001-12
2002-03
2002-06
2002-09
2002-12
2003-03
2003-06
2003-09
2003-12
2004-03
2004-06
2004-09
2004-12
2005-03
2005-06
2005-09
2005-12
2006-03
2006-06
2006-09
2006-12
2007-03
2007-06
2007-09
2007-12
2008-03
2008-06
2008-09
2008-12
2009-03
2009-06
2009-09
2009-12
2010-03
2010-06
Month

Seasonal variation in blood pressure and its relationship with outdoor temperature in 10 diverse regions of China: the China Kadoorie Biobank

Sarah Lewington[a], Liming Li[b,c,d,*], Paul Sherliker[a], Yu Guo[c,d], Iona Millwood[a], Zheng Bian[c,d], Gary Whitlock[a], Ling Yang[a], Rory Collins[a], Junshi Chen[c], Xianping Wu[e], Shaojie Wang[f], Yihe Hu[g], Li Jiang[h], Liqiu Yang[i], Ben Lacey[a], Richard Peto[a], Zhengming Chen[a]

See editorial comment on page 1315

Objectives: Mean blood pressure varies moderately with outdoor air temperature in many western populations. Substantial uncertainty exists, however, about the strength of the relationship in other populations and its relevance to age, adiposity, medical treatment, climate and housing conditions.

Methods: To investigate the relationship of blood pressure with season and outdoor temperature, we analysed cross-sectional data from the China Kadoorie Biobank study of 506 673 adults aged 30–79 years recruited from 10 diverse urban and rural regions in China. Analyses related mean blood pressure – overall and in various subgroups – to mean local outdoor temperature.

Results: The mean difference in SBP between summer (June–August) and winter (December–February) was 10 mmHg overall, and was more extreme, on average, in rural than in urban areas (12 vs. 8 mmHg; *P* for interaction <0.0001). Above 5°C, SBP was strongly inversely associated with outdoor temperature in all 10 areas studied, with 5.7 (SE 0.04) mmHg higher SBP per 10°C lower outdoor temperature. The association was stronger in older people and in those with lower BMI. At lower temperatures, there was no evidence of an association among participants who reported having central heating in their homes.

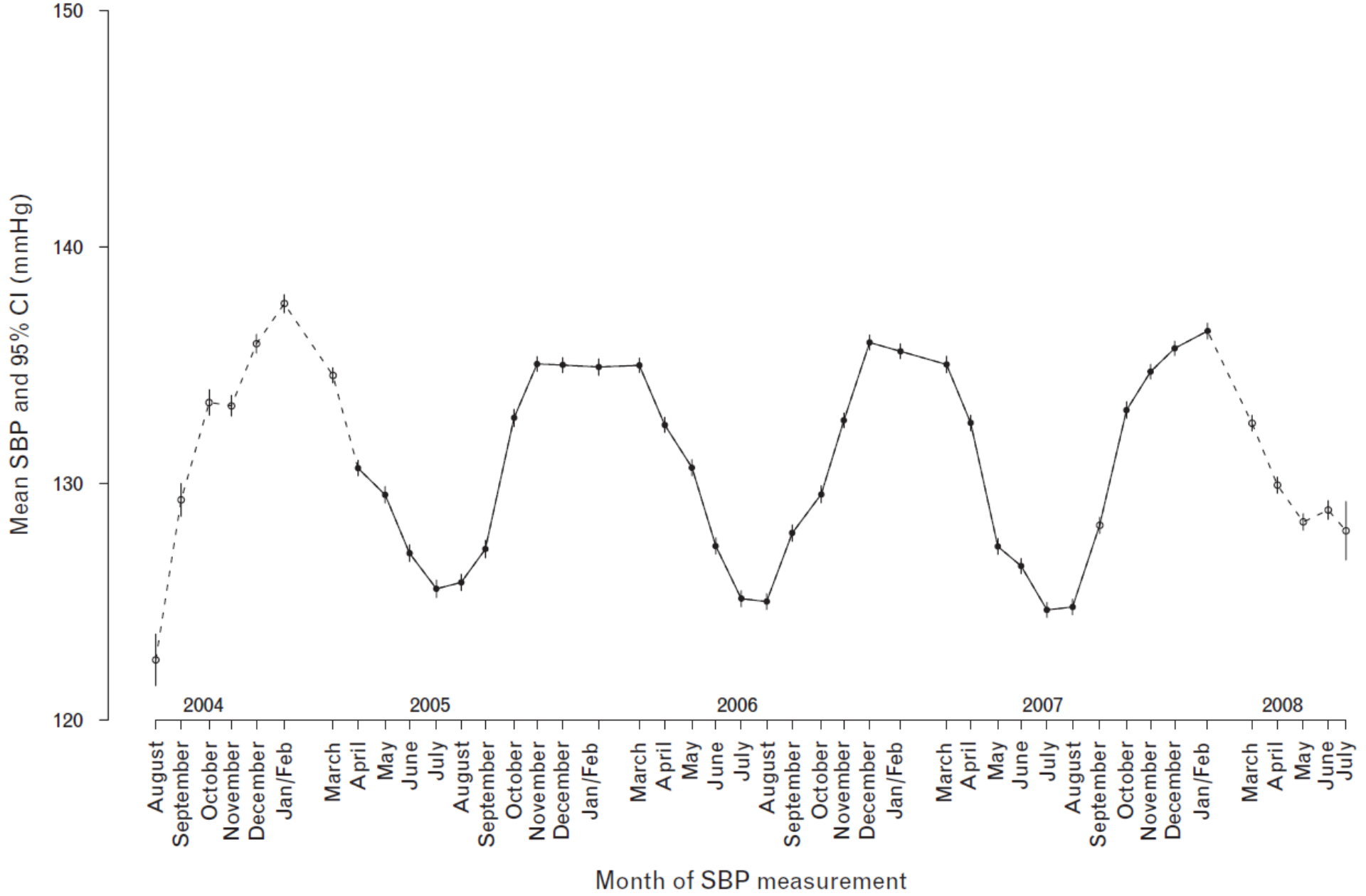
Conclusion: Blood pressure was strongly inversely associated with outdoor temperature in Chinese adults across a range of climatic conditions, although access to home central heating appeared to remove much of the association during the winter months. Seasonal variation in blood pressure should be considered in the clinical management of hypertension.

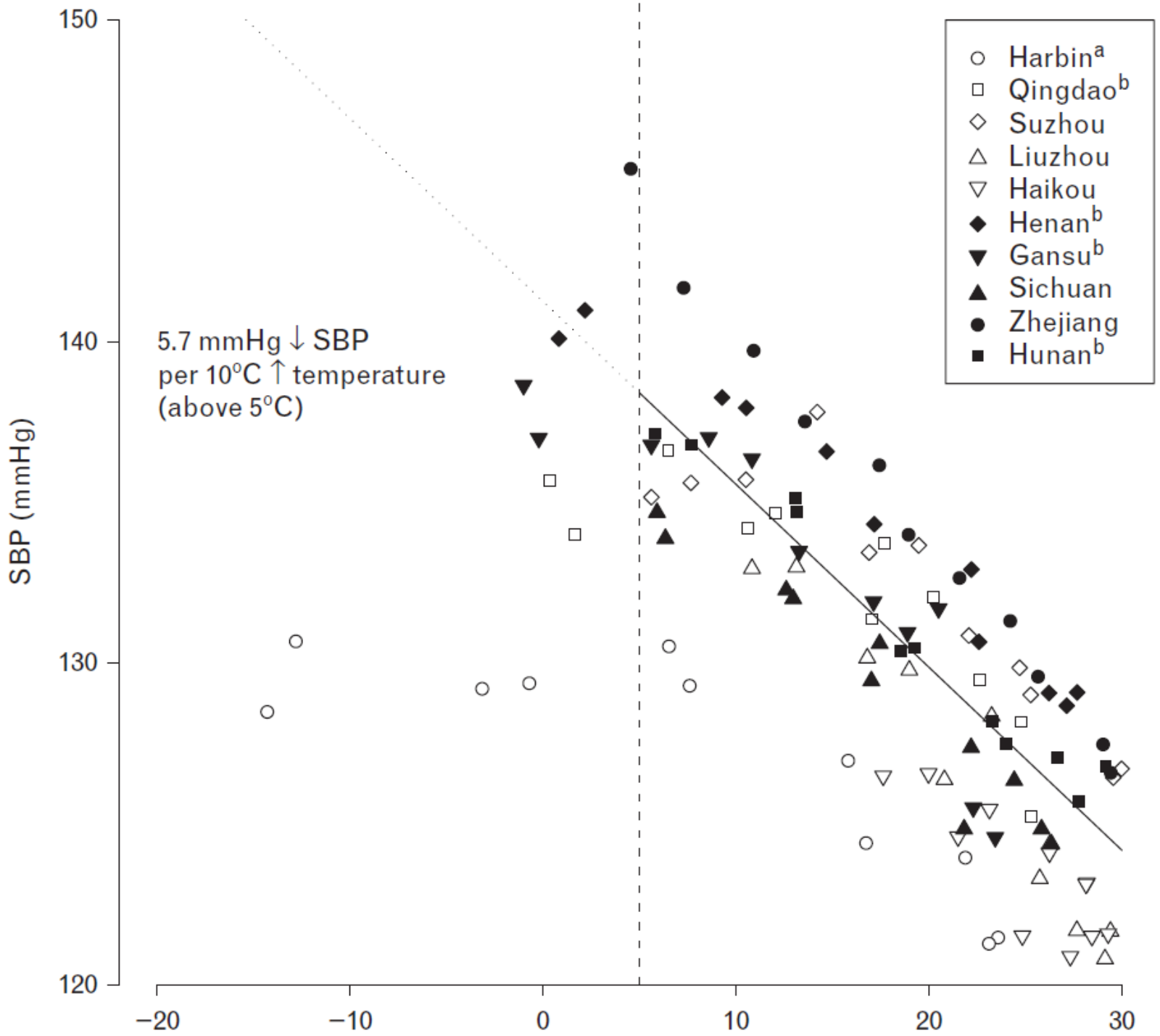
determinants in China and some other developing countries are still poorly understood [3]. In western countries, average SBP among adults is generally higher in winter than in summer, and this variation is considered to be largely mediated through outdoor air temperature [4–7]. Despite this, substantial uncertainty remains about the strength of the association in different parts of the world (especially in low-income and middle-income countries) and whether the association is modified by other climatic conditions (such as humidity), housing conditions (such as central heating), other known determinants of blood pressure (such as age, alcohol drinking and adiposity) or anti-hypertensive treatment.

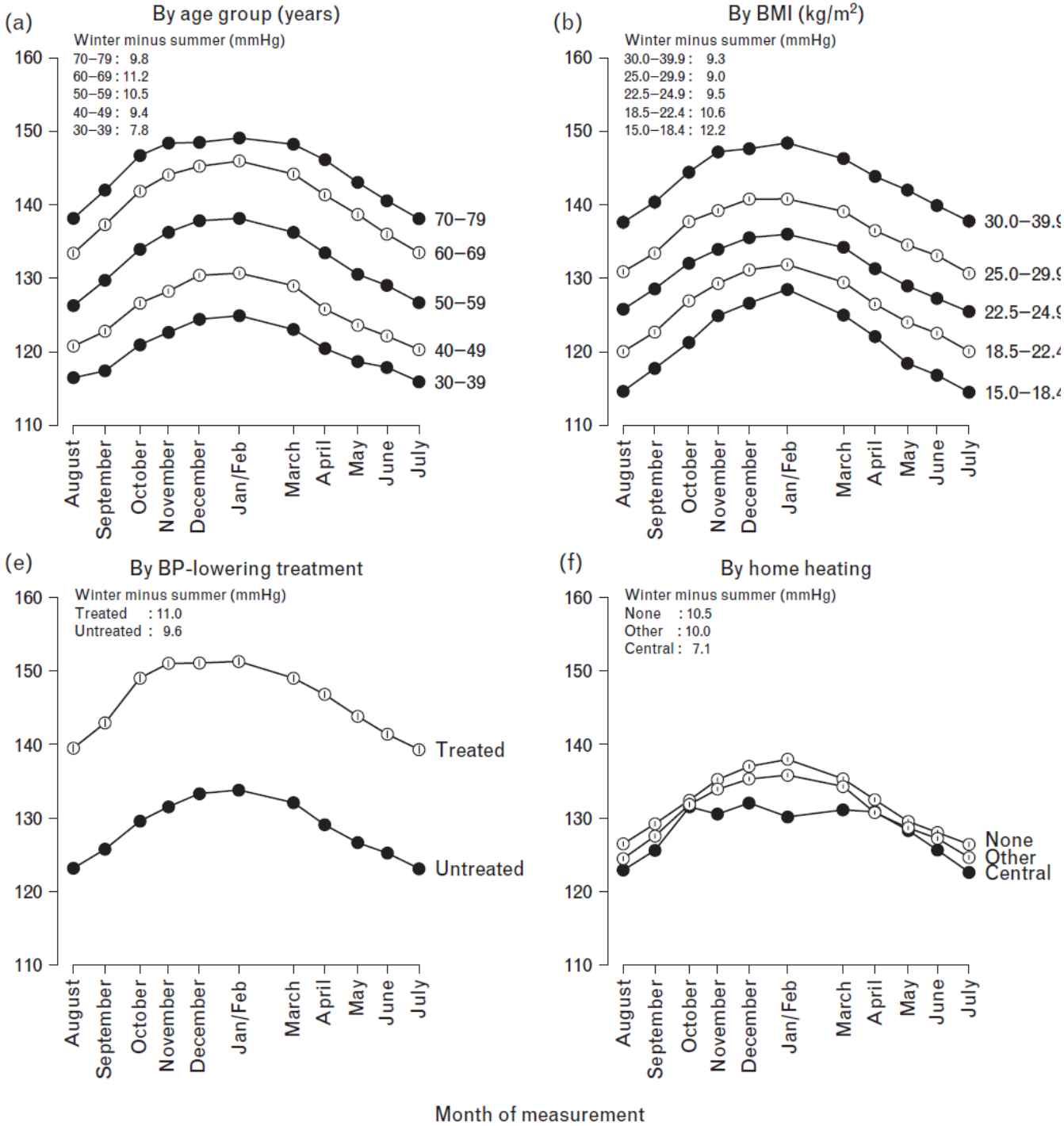
Although regional and seasonal variations in outdoor temperature are unusually large in China (http://2011.cma.gov.cn/en/forecasts/), their relationship with blood pressure in the country has never been examined properly in a large-scale study. We report a large cross-sectional study of the relationships between measured clinic blood pressure, season and outdoor temperature in over 500 000 men and women aged 30–79 years who were recruited from 10 geographically diverse areas of China over a 4-year period.

Journal of Hypertension 2012, 30:1383–1391

[a]Clinical Trial Service Unit and Epidemiological Studies Unit (CTSU), University of Oxford, UK, [b]School of Public Health, Peking University, [c]Chinese Center for Disease Control and Prevention, [d]Chinese Academy of Medical Sciences, Beijing, [e]Sichuan Center for Disease Control, Chengdu, Sichuan, [f]Qingdao Center for Disease Control, Qingdao, [g]Suzhou Center for Disease Control, Suzhou, Jiangsu, [h]Huixian Center for Disease Control, Huixian, Hennan and [i]Nangang Center for Disease Control, Haerbin, Heilongjiang, China


150
140
130
120
Mean SBP and 95% CI (mmHg)
2004
2005
2006
2007
2008
August
September
October
November
December
Jan/Feb
March
April
May
June
July
Month of SBP measurement


150
140
130
120
SBP (mmHg)
−20
−10
0
10
20
30
5.7 mmHg ↓ SBP
per 10°C ↑ temperature
(above 5°C)
Harbin[a]
Qingdao[b]
Suzhou
Liuzhou
Haikou
Henan[b]
Gansu[b]
Sichuan
Zhejiang
Hunan[b]


(a)
By age group (years)
Winter minus summer (mmHg)
70–79 : 9.8
60–69 : 11.2
50–59 : 10.5
40–49 : 9.4
30–39 : 7.8
160
150
140
130
120
110
70–79
60–69
50–59
40–49
30–39
August
September
October
November
December
Jan/Feb
March
April
May
June
July
(b)
By BMI (kg/m²)
Winter minus summer (mmHg)
30.0–39.9 : 9.3
25.0–29.9 : 9.0
22.5–24.9 : 9.5
18.5–22.4 : 10.6
15.0–18.4 : 12.2
30.0–39.9
25.0–29.9
22.5–24.9
18.5–22.4
15.0–18.4
(e)
By BP-lowering treatment
Winter minus summer (mmHg)
Treated : 11.0
Untreated : 9.6
Treated
Untreated
(f)
By home heating
Winter minus summer (mmHg)
None : 10.5
Other : 10.0
Central : 7.1
None
Other
Central
Month of measurement

Summer does not always mean lower: seasonality of 24 h, daytime, and night-time blood pressure

Massimiliano Fedecostante, Paolo Barbatelli, Federico Guerra, Emma Espinosa, Paolo Dessì-Fulgheri, and Riccardo Sarzani

See editorial comment on page 1315

Objective: Evaluation of seasonal influences on ambulatory blood pressure monitoring (ABPM) values in a very large population living in a mild-climate geographic area.

Methods: Among patients referred to our Hypertension Center between September 2002 and January 2011 with a reliable ABPM, we considered those in the two hottest (July and August) vs. those in the two coldest (January and February) months.

Results: Seven hundred and forty-two men (53.2%) and 653 women (46.8%) were studied; 1245 (89.3%) were hypertensive patients of which 795 (63.9%) were drug-treated. In winter, mean daytime SBP and DBP were higher ($P = 0.001$ and $P < 0.001$, respectively), but only 24-h DBP was significantly higher ($P = 0.012$). On the contrary, higher night-time SBP and pulse pressure were recorded in summer ($P = 0.005$ and $P = 0.023$, respectively). Uncontrolled hypertensive patients had the highest mean difference between winter and summer night-time SBP (127.1 ± 13.4 vs. 131.0 ± 12.6 mmHg; $P = 0.001$). In winter a dipping pattern was prevalent (58.2%), whereas in summer a nondipping pattern prevailed (61.9%; $P < 0.001$). Isolated nocturnal hypertension (INH) was present in 9.8% in winter vs. 15.2% in summer ($P = 0.003$).

Conclusion: Our data on a very large ABPM sample confirmed that hottest summer months are associated with lower daytime BP and also lower 24-h DBP. However, we found an inverse relationship regarding night-time BP, dipping pattern, and INH that were higher or more common in summer. These findings were even more evident in treated patients, especially when not at target. Different sleeping behaviors or improper dose reduction of drug therapy in summer may explain the findings.

Keywords: ABPM, isolated nocturnal hypertension, night-time, nondipper, seasonality

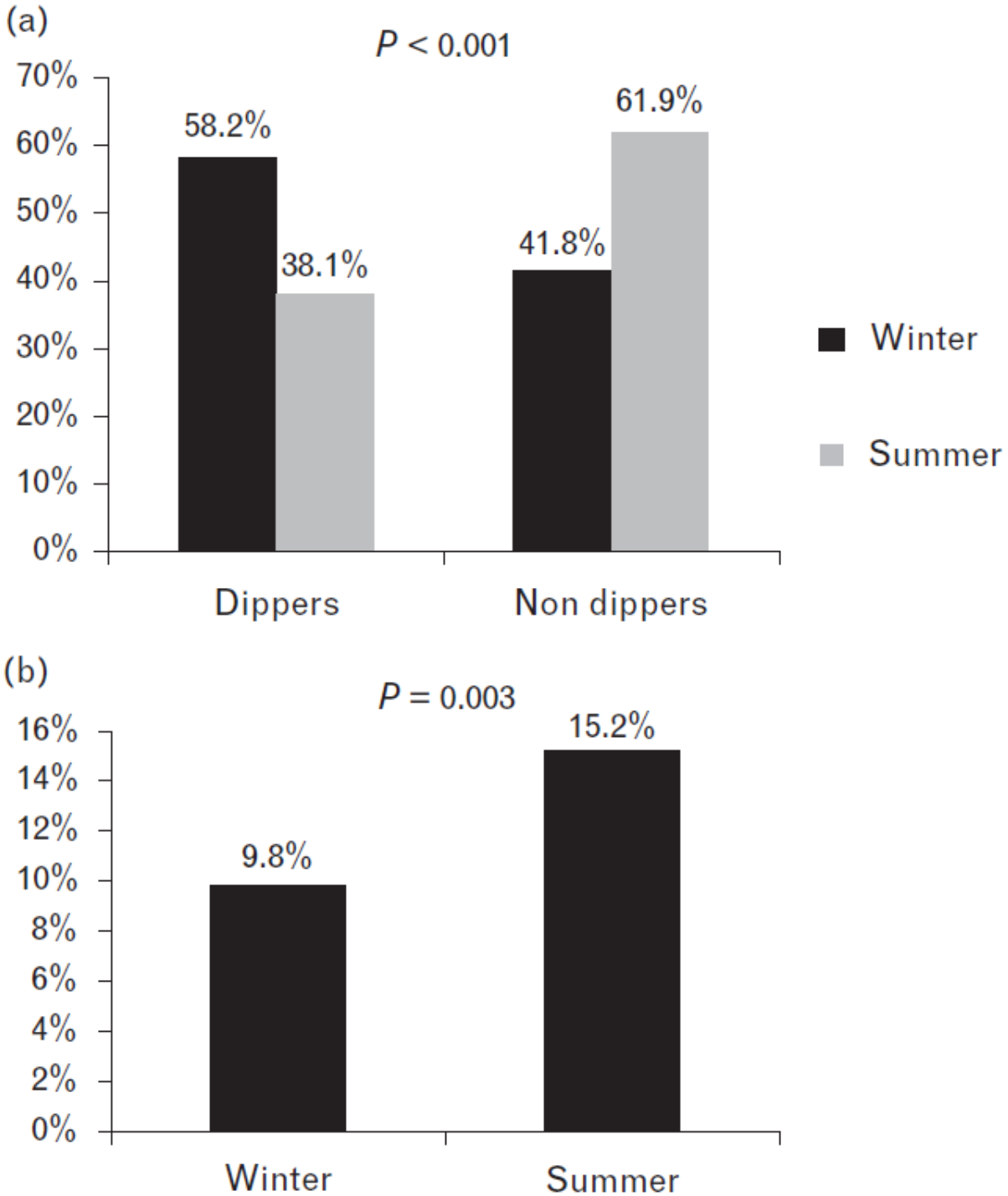
INTRODUCTION

Blood pressure (BP) is highly variable: from beat-to-beat to circannual variability together with aging-related changes across decades. Office BP changes also according to seasons, with the highest values during winter and the lowest during summer [1–9]. Studies focused on seasonal BP variations in hypertensive patients have demonstrated higher prevalence and greater severity of hypertension in winter [10–12].

This phenomenon is probably due to an increase in cold-induced sympathetic nervous system activity, which also leads to increased activity of the renin–angiotensin–aldosterone system (RAAS) [13]. The RAAS appears to play a major role in cold-induced BP increase [14,15]. Some other factors could also be involved in raising BP during winter, such as increased food and salt intake and weight gain [16].

Recent evidences indicate that night-time BP and dipping status are powerful risk factors for organ damage and mortality [17–20]. However, from the few published studies on BP seasonal changes, it is unclear whether night-time BP follows the same pattern [8,11,12]. Among the published studies with larger populations, in the first one with a total of 2051 participants, the ambulatory blood pressure monitoring (ABPM) data were very scanty in the hottest period of the year (about 100 patients in July and none in August) [9].

The aim of this study was to investigate if night-time BP and dipping pattern could vary between winter and summer in a large outpatient population referred to our 'Hypertension Excellence Center' for ABPM during 9 consecutive years. We focused our attention on the two coldest and the two hottest months, examining the average temperatures from 2002 to 2011, in order to facilitate the study of temperature-related differences between winter and summer.


(a)
P < 0.001
70%
60%
50%
40%
30%
20%
10%
0%
58.2%
38.1%
41.8%
61.9%
Winter
Summer
Dippers
Non dippers
(b)
P = 0.003
16%
14%
12%
10%
8%
6%
4%
2%
0%
9.8%
15.2%
Winter
Summer

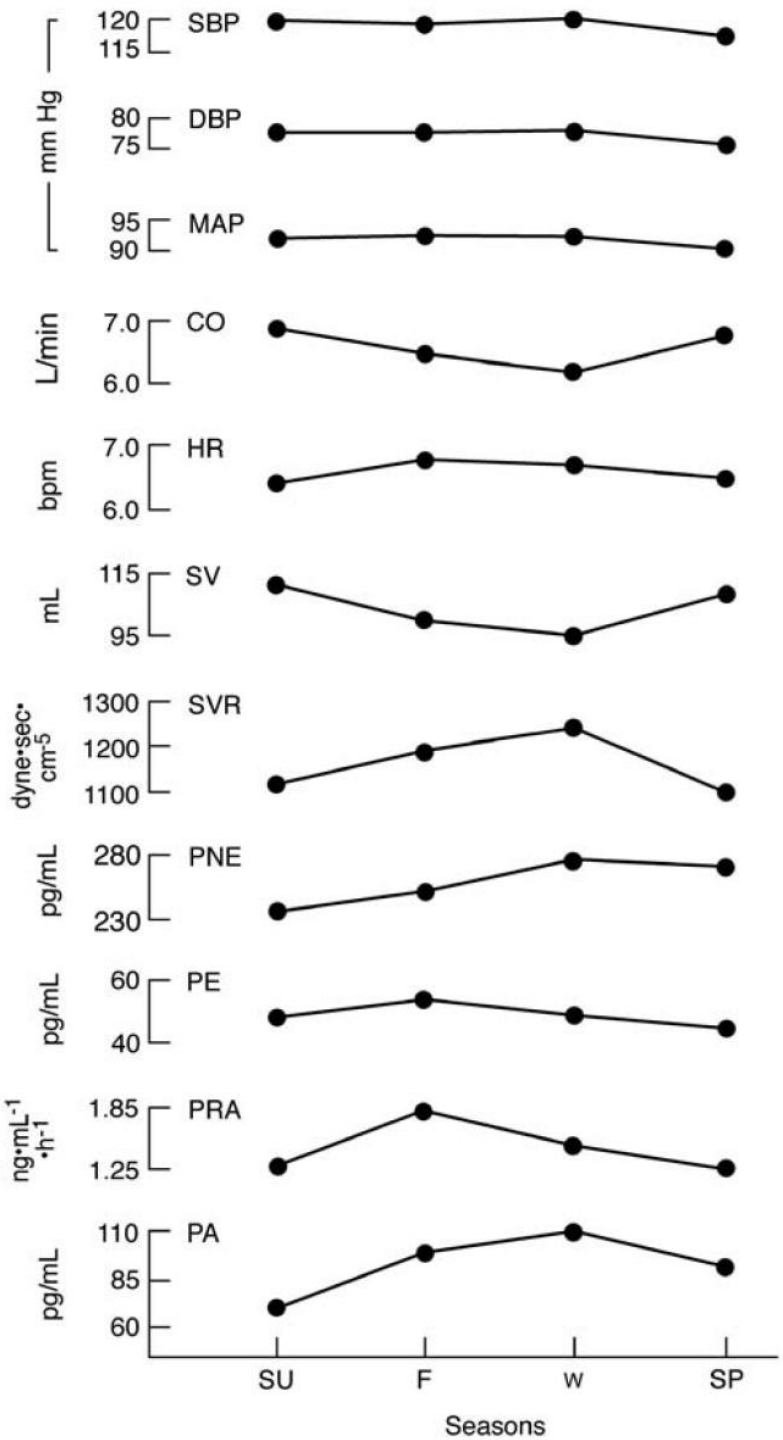
Seasonal variation in haemodynamics and blood pressure-regulating hormones

KJ Radke[1,2] and JL Izzo Jr[1]

[1]*Department of Medicine, Erie County Medical Center, Buffalo, NY, USA and* [2]*School of Nursing, and Department of Physiology and Biophysics, School of Medicine and Biomedical Sciences, University at Buffalo, Buffalo, NY, USA*

Seasonal variation in blood pressure (BP) has been described in some people, although the variation is small for both systolic and diastolic BPs. The aim of this study was to elucidate underlying haemodynamic and hormonal mechanisms that may occur to defend seasonal changes in BP. Participants were 27 men and 7 women with either normal BP or early hypertension. Measurements of haemodynamics (cardiac output by dual-gas rebreathing) and hormones (resting catecholamines, renin activity, and aldosterone by radioenzymatic assay or radioimmunoassay) were performed during the summer, fall, winter, and spring seasons. Student's paired *t*-test with Bonferroni modification and regression analyses were used to examine the data with a significance level of $P<0.05$. Systolic and diastolic BP remained relatively constant across seasons. Cardiac output and stroke volume significantly decreased 10 and 15%, respectively, from summer to winter, whereas heart rate and systemic vascular resistance significantly increased 5 and 11%, respectively. Plasma aldosterone (PA) significantly increased 59% from summer to winter, whereas plasma norepinephrine (PNE), plasma epinephrine, and plasma renin activity (PRA) increased 19, 2, and 17%, respectively (pNS for each). Across the four seasons, mean arterial pressure significantly correlated with PRA and PA, whereas systemic vascular resistance significantly correlated with PNE and PRA. There are dramatic counterregulatory haemodynamic and hormonal adaptations to maintain a relatively constant BP. Norepinephrine, PRA, and aldosterone have a function in mediating the changes in haemodynamics.

Journal of Human Hypertension (2010) **24,** 410–416; doi:10.1038/jhh.2009.75; published online 24 September 2009


mm Hg
120
115
SBP
80
75
DBP
95
90
MAP
L/min
7.0
6.0
CO
bpm
7.0
6.0
HR
mL
115
95
SV
dyne•sec•cm-5
1300
1200
1100
SVR
pg/mL
280
230
PNE
pg/mL
60
40
PE
ng•mL-1•h-1
1.85
1.25
PRA
pg/mL
110
85
60
PA
SU
F
W
SP
Seasons

Seasonal variation of endothelium-dependent flow-mediated vasodilation measured in the same subjects

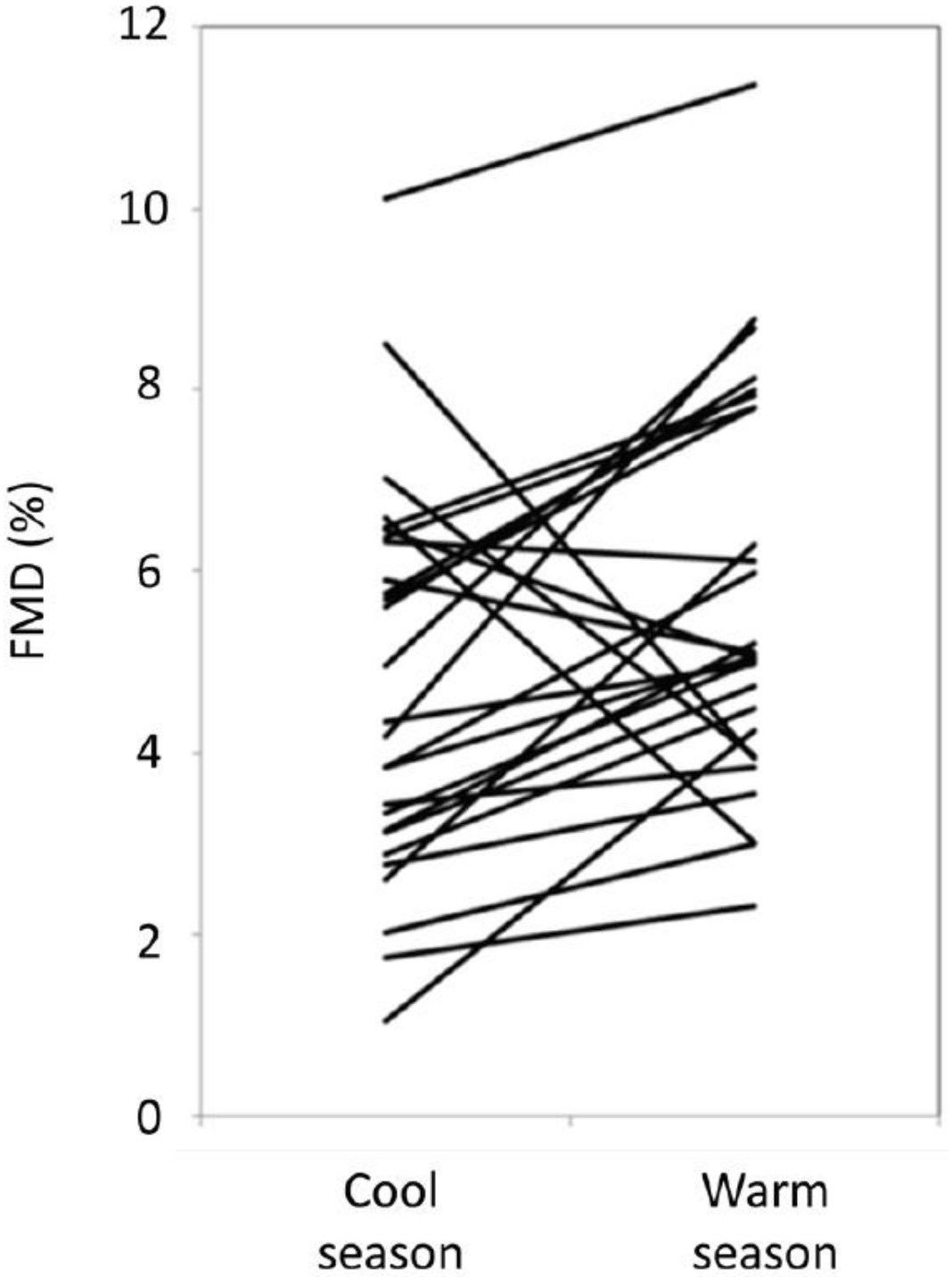
Masako Iwata[1], Yutaka Miyashita[2], Hiromichi Kumagai[1]

[1]Department of Clinical Nutrition, School of Food and Nutritional Sciences, University of Shizuoka, Shizuoka, Japan; [2]Miyashita Clinic, Shizuoka, Japan

Received March 1, 2012; accepted April 5, 2012; Epub May 15, 2012; Published June 15, 2012

Abstract: Background: Seasonal variation of flow-mediated vasodilation (FMD) remains controversial. A large cohort study showing that FMD was highest in summer and lowest in winter has been performed in a cross-sectional manner on different populations in different seasons, and the results for the same population were not compared. Methods: FMD was compared between the cool season (14.4 ± 4.4°C) and warm season (28.8 ± 1.0°C) in the same 27 outpatients with hypertension, diabetes mellitus and/or hyperlipidemia. Results: The mean resting brachial artery diameter was significantly larger in the warm season than in the cool season. The maximal post-deflation brachial artery diameter was also significantly larger in the warm season than in the cool season. FMD, which was calculated from the resting diameter and the maximal diameter, was significantly higher in the warm season than in the cool season even when expressed as the relative value (4.74 ± 2.15 vs. 5.71 ± 2.17%, p=0.03) or absolute value (0.18 ± 0.08 vs, 0.23 ± 0.07 mm, p=0.008). Conclusions: FMD was significantly higher in the warm season than in the cool season when the measurements were performed on the same subjects and a paired comparison was made.

Am J Cardiovasc Dis 2012;2(2):111-115


12
10
8
6
4
2
0
FMD (%)
Cool season
Warm season