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Original Paper

Seasonality of Hypertension

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In this study, a group of controls and patients with essential hypertension were followed up for 1 year. Four measurements at different day temperatures were performed. In each visit, blood pressure, serum total cholesterol, and high-density lipoprotein cholesterol (HDL-C) were measured. The results showed a significant inverse relationship between mean blood pressure and serum total cholesterol levels with day temperature, while a direct relationship was observed for HDL-C value. These results suggest that in areas where significant changes in day temperature and daylight duration exist at different times of the year, blood pressure, serum cholesterol, and HDL-C levels change accordingly in a cycle with higher blood pressure and serum total cholesterol and lower HDL-C values in the coldest season. (J Clin Hypertens (Greenwich). 2008;10:125–129)

Seasonal variation in blood pressure (BP) has been described in hypertensive patients,[1,2] in renal transplant recipients,[3] in hemodialysis patients,[4] in healthy persons,[5,6] and after exercise.[7] This variation has been observed in patients with treated and untreated hypertension.[8] Previous work in this field suggests that there is an inverse correlation between BP and environmental temperatures.[8,9] Increased BP at lower environmental temperature has been attributed to increased sympathetic nervous activity and an increased load of sodium presented to the kidney for excretion,[1] while a decrease in BP has been attributed to length of daylight[3] and increased sweating, with the inevitable loss of sodium.[10]

Seasonal changes of serum biochemical parameters may have a direct effect on BP.[11] Seasonal variations in serum cholesterol level have been observed by several investigators.[12–16] The difference (summer compared with winter) could be as high as 100 mg/dL (2.6 mmol/L) in areas with extreme changes in environmental temperatures,[16] while only small changes have been observed in areas with less drastic seasonal environmental changes.[12] These changes are found equally in men and women (with some marginal differences) and in healthy and hyperlipidemic persons.[16]

Residents of Mosul (in northern Iraq) enjoy diverse climatic changes throughout the year, from a very hot summer season (June, July, and August) with day temperatures >40°C (104°F) and daylight of 14 to 15 hours to a cold winter (December and January) with day temperatures around 10°C (50°F) and daylight of 9 to 9.5 hours. The rest of the year normally has temperate climates. Therefore, it was the intention of this work to study the effect of a hot climate on BP in normotensive and hypertensive persons and its relationship to serum cholesterol level and atherogenic index.

MATERIALS, PARTICIPANTS, AND METHODS

Participants

In this study, we examined 70 hypertensive patients (24 men and 46 women receiving treatment with BP-lowering drugs and without diuretics) with an age range of 47 to 60 years. According to the World Health Organization classification system, most of the participants had stage 2 and stage 3

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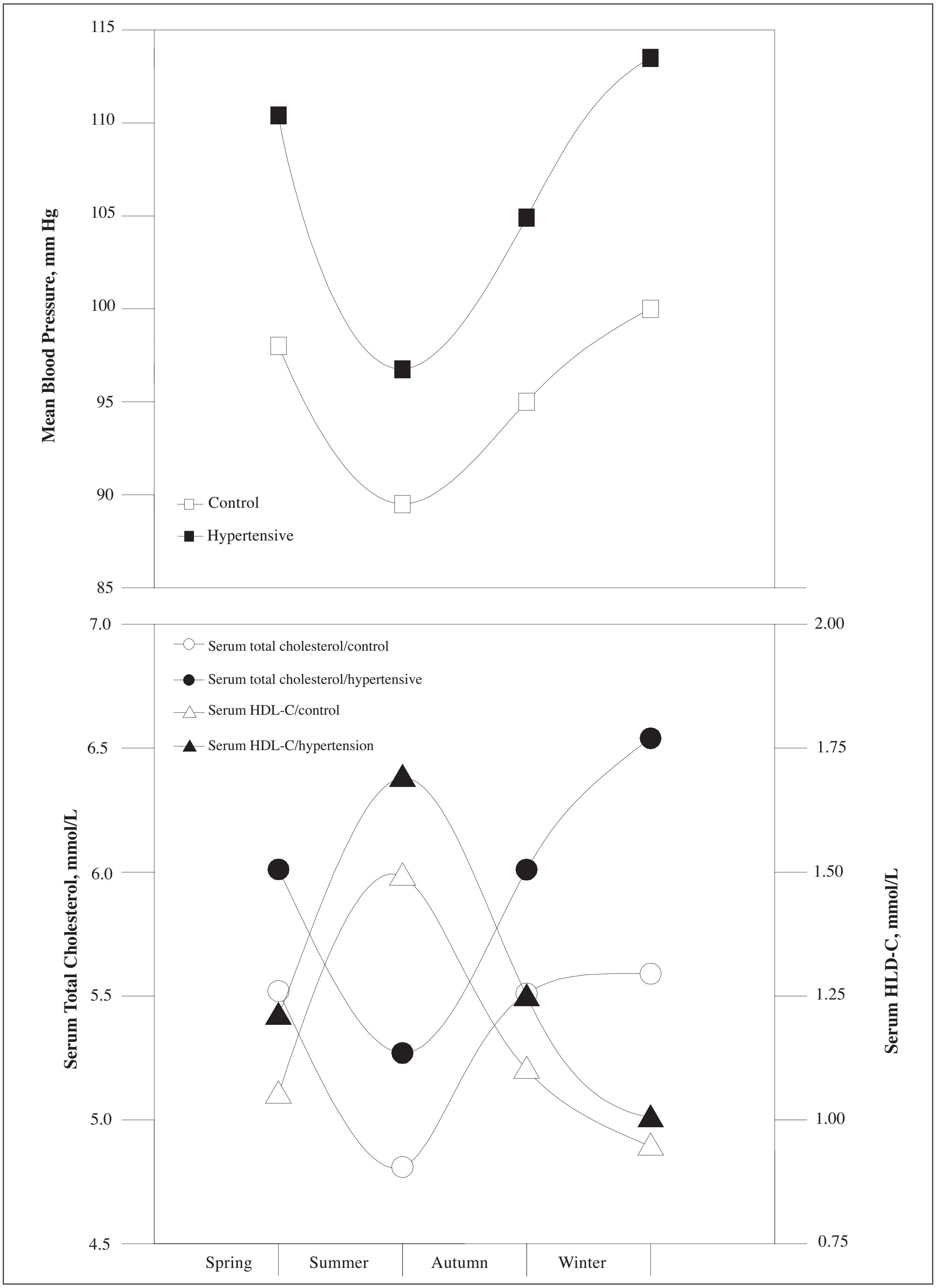

Figure. Mean blood pressure, serum total cholesterol, and high-density lipoprotein cholesterol (HDL-C) in different seasons.

hypertension.[17] A control group of 50 apparently healthy persons (25 men and 25 women) aged 45 to 58 years was also included in this study.

All participants were followed up for 1 year, from spring 2003 to winter 2004, and were informed on the nature and purpose of the study.

Follow-up at the Mosul Meteorological Office was as follows: (1) during April (mean day temperature, 22°C [71.5°F]; humidity, 90.7%); (2) during July (mean day temperature, 44.3°C [112°F]; humidity, 42.1%); (3) during October (mean day temperature, 32°C [89.5°F]; humidity, 64.4%); and (4) during January (mean day temperature, 14.7°C [58.5°F]; humidity, 88%).

Dietary habits remained almost unchanged during the period of study, and the only difference between the 2 groups was that hypertensive participants were salt-deprived while the control participants were not. The average weight of the participants at the 4 visits did not show much variation. In the control participants, the weight range in winter was 49 to 106 kg (mean, 73.4 kg), and in summer it was 48 to 105 kg (mean, 73.6 kg). In the hypertensive participants, the average weight in winter was 50 to 114 kg (mean, 79.1 kg), and in summer it was 49 to 113 kg (mean, 78.7 kg). In both cases, the difference was insignificant.

Specimens

All participants were asked to refrain from eating overnight (14–16 hours) before coming to the clinic. During each of the 4 visits, venous blood was drawn. Blood samples were allowed to clot in plain tubes for 15 minutes at room temperature and centrifuged at 1200 rpm; serum samples were then placed in capped glass tubes and kept frozen at –18°C for no more than 2 weeks before being analyzed. At each visit, BP was measured with a mercury sphygmomanometer in the sitting position after 10 minutes' rest.

Methods

Blood Pressure. In each participant, systolic and diastolic BP values were measured and recorded (Table I). The measurements were performed by a consultant cardiologist (one of the authors) using a mercury sphygmomanometer (at least 3 measurements were taken for each participant during the day of each visit). Then, the mean BP level was calculated according to the following formula.[18]

Mean BP = diastolic pressure + 1/3 (systolic pressure – diastolic pressure.)

Serum Total Cholesterol. Serum total cholesterol was determined by enzymatic method using a kit supplied by Biocon Diagnostic (Marienhaged, Germany). The method was dependent on the hydrolysis of cholesterol ester: oxidizing cholesterol, then reacting the resulting H_2O_2 with phenol and 4-aminoantipyrine to produce a colored quinoneimine that can be measured spectrophotometrically at 500 nm.

Serum High-Density Lipoprotein Cholesterol. High-density lipoprotein cholesterol (HDL-C) was measured by precipitating very-low-density lipoprotein and low-density lipoprotein cholesterol by phosphotungstic acid and magnesium chloride. The remaining supernatant contains mainly HDL-C. The HDL-C value was then determined by the same method described above.

Serum Albumin. Serum albumin was determined colorimetrically using a method based on the binding of albumin with bromocresol green. The formed complex was then quantitated by measuring the optical density at 578 nm.[19]

RESULTS

All results were expressed as mean ± SD. For comparison among different seasons in each group, the values for April were considered as a baseline. For comparison between the mean of 2 groups (either control against hypertensive or spring compared with other seasons), *t* test was used. *P* values ≤.05 were considered significant.

Mean BP

Table I shows the range and the mean of diastolic and systolic BP levels of the 2 studied groups in different seasons of the year. Mean BP values and all other results obtained throughout the study are summarized in Table II.

The values of hypertensive participants were significantly higher than the values of normotensive persons in all seasons. In both groups, the values for other months were significantly different from April values. Peak levels occurred in January, and the lowest values were in July, with a significance of *P*<.001.

Serum Albumin

In both hypertensive and normotensive participants, serum albumin values obtained in July were significantly higher than those obtained in April (*P*<.001), whereas the results obtained in October and January were not significantly different in both groups. This is an indication of dehydration in the summer season for all the participants.

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Table I. Systolic and Diastolic BP in Different Seasons in Control (n=50) and Hypertension (n= 70) Groups

Participants	BP	Spring	Summer	Autumn	Winter
Control	Systolic	118.2–130.1 (126.2±3.3)	110.6–126.4 (118.2±6.5)[a]	116.1–129.3 (124.6±2.8)[b]	120.6–133.3 (130.6±2.8)[c]
	Diastolic	76.3–84.5 (82.1±2.3)	72.1–82.6 (78.5±3.5)[c]	75.1–83.5 (81.3±3.7)	80.3–86.5 (84.1±2.3)[c]
Hypertension	Systolic	137.4–145.2 (140.6±2.9)[d]	128.2–134.3 (130.6±2.9)[a,d]	131.4–140.2 (135.7±3.9)[c,d]	142.4–150.2 (147.6±2.1)[a,d]
	Diastolic	87.5–96.1 (92.8±2.8)[d]	82.3–86.9 (85.1±3.3)[a,d]	84.3–91.5 (88.6±3.5)[c,d]	89.3–98.5 (94.1±3.3)[c,d]

Values are presented as range (mean ± SD). Significant difference between spring and other seasons at [a]P≤.001; [b]P≤.05; and [c]P≤.01. Significant difference between control and hypertension group at [d]P≤.001. Abbreviation: BP, blood pressure.

Table II. Laboratory Values in Different Seasons in Control (C) (n=50) and Hypertension (H) (n=70) Groups

	Group	Spring	Summer	Autumn	Winter
MBP, mm Hg	C	98.12±4.38	89.48±4.52[a]	94.96±3.82[a]	100.17±4.03[a]
	H	110.14±10.1[b]	96.78±10.1[a,b]	104.88±9.62[b]	113.5±9.7[a,b]
SA, g/L	C	45.3±6.0	50.6±7.9[a]	45.7±5.3	43.7±5.4[a]
	H	44.2±6.3	49.2±7.2[a]	44.8±6.9	42.5±6.5[a]
STC, mmol/L	C	5.57±1.13	4.81±0.92[c]	5.56±1.20	5.9±1.34
	H	6.1±1.09[b]	5.27±0.83[a,b]	6.09±1.00[b]	6.54±1.33[b,c]
SHDL-C, mmol/L	C	1.05±0.49	1.48±0.53[a]	1.1±0.47	0.89±0.36[d]
	H	1.21±0.55	1.68±0.63[a]	1.26±0.53	1.01±0.5[b,d]
AI[e]	C	4.30±0.26	3.20±0.13[a]	4.4±0.23[d]	4.70±0.34[a]
	H	5.83±0.34[b]	3.45±0.15[a,b]	5.48±0.29[b,d]	6.68±0.46[a,b]

Values are mean ± SD. Significant difference between spring and other seasons at [a]P≤.001. Significant difference between C and H group at [b]P≤.001. Significant difference between spring and other seasons at [c]P≤.01 and [d]P≤.05. [e]Atherogenic index (AI) = total cholesterol/high-density lipoprotein cholesterol. Abbreviations: C, control; H, hypertension; MBP, mean blood pressure; SA, serum albumin; SHDL-C, serum high-density lipoprotein cholesterol; STC, serum total cholesterol.

Serum Total Cholesterol and HDL-C

As shown in Table II, the values for total cholesterol in the control group were significantly lower (P<.05) than in the hypertensive group in all seasons. In both groups, the values in the summer were lowest and were highest in winter. HDL-C values, on the other hand, were not statistically different between the control group and the hypertensives in any seasons; however, seasonal differences in both groups were significant between spring and summer values (P<.01) and summer and winter values (P<.001).

When comparing the atherogenic index, it was found that the difference between spring and summer values and between winter and summer values were significant at P<.001.

DISCUSSION

BP and Environmental Temperature

A strong link between mean BP and environmental temperature was observed (Figure). Changes among the 4 readings (January, April, July, and October) both in normal and hypertensive participants were significantly different, at P<.001. Lower BP values were observed with higher temperatures. These results agree with earlier findings.[6–8] These variations raise the question of BP measurement standardization in relation to "ambient temperature" and length of daylight because the results suggest that environmental temperatures play an important role in determining BP values, particularly where ambient temperatures have great seasonal fluctuation, as seen in Mosul.

The Effect of Ambient Temperature on Cholesterol and HDL-C Concentration

Several previous reports have indicated that serum total cholesterol levels are higher in winter than in summer. The difference was found to be about 4%.[14] In our study, it appears that the difference could be higher (>10%); that may be explained on the basis of the severity of the daytime temperature in Mosul during the summer months. On the other hand, HDL-C levels in this study showed a reciprocal pattern contrary to what has been found.[20,21] Combining the results of both total cholesterol and

HDL-C in this study, it appears that there may be some factors that play major roles in both decreasing total cholesterol and increasing HDL-C in the summer. There seemed to be no reduction in albumin levels in the summer compared with the winter, indicating no hypervolemia in the summer months (which may explain the reduction in cholesterol level), as suggested by Ockene and colleagues.[15]

To explain these variations, it was suggested that a decrease in lipoprotein lipase activity in the summer (both in adipose tissue and skeletal muscles) due to increased physical activity, high temperature, and increased exposure to sunlight may be responsible.[14] In our opinion, one or more of the following factors may have contributed to this phenomena:

- Increasing activity of lecithin-cholesterol acyltransferase in the higher environmental temperature favors the increase in the formation of HDL-C at the expense of reducing other fractions of cholesterol and, subsequently, total cholesterol.
- An increase in the excretion of bile acids in the summer.
- A decrease in the activity of cholesterol synthesis in the summer due to increased physical activity and reduction in the level of acetyl coenzyme A.
- An increase in the rate of vitamin D synthesis due to longer exposure to daylight.

The results of this study suggest that the increased rates of death during the winter that is observed in many countries may be due to low environmental temperature.[22] Colder weather, as seen in this study, favors atherogenic factors and increasing mean BP, while these factors are reversed in the warmer weather. This study also raises the issue of changing levels of lipids, in particular, total cholesterol and its fraction, during different environmental temperature.

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