Seasonal variation in blood pressure in normotensive women studied by home measurements

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INTRODUCTION

A seasonal variation in arterial blood pressure (BP) has been demonstrated [1–7], with BP being lower during the summer than in the winter [1–6]. Although a seasonal variation has been observed in patients with essential hypertension, it is not known whether this also occurs in normotensive subjects [4, 5]. The information on the seasonal variation in BP appears to have been based mainly on so-called ‘clinic’ or ‘casual’ measurements of BP [2–6]. The reliability of BP measurements in the clinic in identifying a small change in BP may be limited by such factors as circadian variation in BP, sporadic and random variation in BP, ‘white coat’ effect and observer bias. It seems that obtaining the average large number of BP measurements using automatic BP monitoring devices in fixed and non-medical settings reduces the influence of factors that affect BP variation and observer bias. Thus, BP information can be precisely obtained, increasing the sensitivity for detecting changes in BP [8–11]. Self-recorded home BP measurements and/or ambulatory BP monitoring are used to overcome this problem. In a small study, Giaconi et al. [7] recently reported that ambulatory BP monitoring detected a seasonal influence on BP. It is apparent that the ambulatory and home measurements of BP provide different information; the former provides information on the daily average and the variation of the BP within a certain day, while the latter gives information based on the long-term average and variation in BP.

In the present study, we evaluated the factors influencing the seasonal variation in BP. We evaluated data collected in 16 normotensive housewives who measured their BP at home virtually every day for more than one year; we selected...
housewives to exclude the influence of job strain on BP. If a seasonal variation of BP existed in these subjects, this procedure would provide quantitative information on the relation between BP and environmental temperature or daytime length. To quantitatively assess circannual variation, an efficient statistical and mathematical method is necessary. The cosinor method has proved to be very useful for assessing physiological rhythm [12, 13]. In the present study, we used the cosinor method to analyse circannual BP rhythm.

METHODS

Subjects

Sixteen subjects were recruited for this study (aged 56.3 ± 7.9 years; range from 40 to 68 years, 58.7 ± 10.5 kg, 156.5 ± 8.4 cm, mean ± SD). The subjects were all housewives. The subjects were referred to, or visited, Tohoku University Hospital or its related hospital (Kojin-kai Hospital) for a detailed examination of hypertension between 1986 and 1990. At routine regional health screening examinations, their BP once exceeded 140 mmHg systole and/or 90 mmHg diastole, but had not been treated with antihypertensive agents. In the following visits to the clinic, however, their BP levels as determined in the clinic did not exceed 140 mmHg systole and/or 90 mmHg diastole. Routine laboratory tests detected no cardiovascular, renal and neural disorders. After obtaining the subjects' informed consent, we conducted a follow-up study including a routine physical examination and laboratory tests for more than one year without the administration of medication. The study was carried out in accordance with the Declaration of Helsinki (1989) of the World Medical Association and was approved by the Institutional Review Board at Tohoku University School of Medicine.

BP measurements

One month after their first visit to the clinic, each subject received training on the technique of self-measurement of BP by physicians and nurses, and was then instructed in how to measure BP at home. Home BP measurements were performed using a previously calibrated, fully automatic device that was based on the cuff-oscillometric principle (OMRON HEM 701C; OMRON Life Science, Kyoto, Japan). This digital device gives the pulse rate (PR) as well as the systolic blood pressure (SBP) and diastolic blood pressure (DBP). The device was calibrated as reported previously [14]. Its function satisfied the criteria of the Association of the Advancement of Medical Instrumentation (AAMI); i.e. the mean differences between the average of two physicians' auscultations and HEM 701C determination was 1.6 ± 7.7 mmHg for SBP and −2.4 ± 6.1 mmHg for DBP (mean ± SD, n = 293) [14]. Devices were calibrated at least once a year and were verified to meet the criteria of the AAMI.

Home measurements of BP in the morning have been shown to aid the subjects' compliance in self-measuring BP [15]. We therefore asked each subject to measure her BP at home each morning. Measurements were taken from the non-dominant arm once within an hour of waking while the subject was seated, and after resting for at least 2 min. Typically, BP was measured between 06:00 h and 08:00 h in the bedroom or the living room.

Subjects visited the clinic every 2–4 weeks for determination of BP and weight in the clinic. We measured BP in the clinic using a conventional mercury sphygmomanometer with the patient seated and after resting for at least 2 min. The average of two consecutive BP measurements at each visit was regarded as office BP. For any subjects who visited the clinic twice a month the average of two office BPs provided the monthly average office BP. Home BP measurements were performed by the subjects for at least 1.5 years. Only those who visited the Kojin-kai Hospital were weighed at every visit while in their underwear and without shoes. Subjects were weighed at their first visit to Tohoku University Hospital and yearly thereafter.

Environmental temperature and daytime length

Data on mean daily temperature and the highest and lowest temperatures for 5 years were obtained from the Sendai Meteorological Observatory. The monthly average of the outdoor temperature was calculated, and we obtained the 12 monthly means of outdoor temperatures for 5 years (1986–1990). The daily indoor temperature at 07:00 h was also determined throughout 1990. Considering that 12 of the 16 subjects lived in wooden houses and the remaining four in reinforced concrete houses, we used two wooden houses and two reinforced concrete houses in Sendai City for measurement of indoor temperature. Since recent houses in the Sendai area have been well air-conditioned, yearly variation of indoor temperature in wooden houses was similar to that in reinforced concrete houses. The ambient temperature in the living room and bedroom of each house was determined at 07:00 h daily in 1990; these values were averaged for each house. The average room temperature in the four houses was considered to be the representative morning indoor temperature in Sendai City. The 12 monthly means of room temperature were obtained. Data on the mean possible duration of sunshine (daytime length) was also obtained from the Sendai Meteorological Observatory. The ambient temperature in the clinic was constant at 24 ± 2°C.

Data analysis

Home and office BPs that were obtained during the first 6 months of the study were excluded from the following analysis. The monthly mean and SD of SBP, DBP and PR obtained at home were
calculated for each subject. Data for the consecutive 12 months were required to be admitted to the analysis of yearly variations in the self-recorded BP and PR. Since we obtained at least 20 measurements per month, at least 240 measurements of home BP and PR were available per year for each individual for the analysis of seasonal variation of each parameter.

The difference of monthly home or casual BP mean (January to December) from each of the annual mean values was calculated in each individual for further analysis. We also calculated the difference in outdoor temperature, indoor temperature, daytime length and weight each month from the annual mean values. An off-line computer (NEC-PC9801 VX2, Nihon denki, Tokyo, Japan) calculated three cosinor parameters (mesor, amplitude and acrophase) from the monthly mean values of SBP, DBP and PR in each subject [16]. The three cosinor parameters from the monthly mean values of outdoor temperature, indoor temperature, daytime length and weight were also calculated. The details of cosinor analysis have been reported previously [16].

Values were expressed as mean ± SD unless stated otherwise. Cosinor parameters were compared by Student's t-test. Linear regression analysis was used to evaluate the correlation between the physiological parameters and environmental temperature or between the physiological parameters and the length of day. A level of \( P < 0.05 \) was accepted as statistically significant.

RESULTS

Background of data

All subjects were more than 40 years of age (aged 56.3 ± 7.9 years). Their office BP was below 140 mmHg systole and 90 mmHg diastole (128.2 ± 9.1/82.5 ± 6.2 mmHg). Their home BP levels were below 139 mmHg systole and 86 mmHg diastole (124.7 ± 8.1/78.2 ± 5.7 mmHg). The 139/86 mmHg levels were the 95th percentile values of the home BP level obtained in normotensive subjects by screening BP determination in an epidemiological survey in a community in northern Japan [21]. Those levels were arbitrarily established as the upper level of normal of the home BP [15].

The annual mean indoor temperature, mean outdoor temperature, the maximum outdoor temperature and mean daytime length were 17.7 ± 5.7°C, 12.1 ± 8.1°C, 16.0 ± 8.0°C, 8.6 ± 8.3°C and 12.2 ± 1.9 h, respectively.

Seasonal variations in BP, environmental temperature, daytime length and body weight

The seasonal variations in office BP, home BP, PR, body weight, indoor temperature, mean outdoor temperature and daytime length appear in Fig. 1 as differences from respectively mean annual values. The home SBP and the home DBP increased in the winter and decreased in the summer. The lowest levels of home SBP and DBP were observed in July. The longest day is in June, while the highest levels of indoor and outdoor temperature were observed in August (Fig. 1). The lowest levels of indoor and outdoor temperature were observed in January and the highest level of home SBP was also observed in January (Fig. 1). The highest level of home DBP was in December (Fig. 1). The shortest day was observed in December (Fig. 1). Although the office BP also tended to decrease during the summer and to increase in the winter, the office SBP in August tended to exceed the annual mean value. No clear relation existed between the season and office DBP.

Cosinor parameters of circannual variation of
daytime length, environmental temperature, BP and PR are represented in Table 1.

When the yearly variability in BP is represented as the SD in yearly average of home BP or office BP, the SD in office SBP (10.5 ± 1.9 mmHg) was significantly larger than that obtained in home SBP (8.4 ± 2.1 mmHg, P < 0.01). Body weight did not change between summer (June, July and August) and winter (December, January and February) seasons (n = 9, 58.4 ± 10.4 kg in summer compared with 58.3 ± 10.4 kg in winter).

**Correlation between changes in home BP and environmental temperature or length of day**

Measurements of home BP were well correlated with those of environmental temperature (home SBP versus mean outdoor temperature: Y = -0.20X + 127.1, r = -0.90, P < 0.001; home DBP versus mean outdoor temperature: Y = -0.13X + 79.7, r = -0.85, P < 0.001; home SBP versus mean indoor temperature: Y = -0.28X + 129.8, r = -0.92, P < 0.001; home DBP versus mean indoor temperature: Y = -0.20X + 81.6, r = -0.88, P < 0.001, where Y is home BP and X is environmental temperature). Although the office SBP level tended to be correlated with the environmental (indoor) temperature (r = -0.45, 0.1 > P > 0.05), the office DBP level was not correlated with the environmental (indoor) temperature (r = 0.12, P < 0.1).

We estimated that a 1°C change in mean indoor temperature accompanied a change in home SBP and home DBP of 0.28 mmHg and 0.20 mmHg, respectively, while a 1°C change in mean outdoor temperature resulted in a change of 0.20 mmHg and 0.13 mmHg, respectively.

The pulse rate was significantly correlated with environmental (indoor) temperature in a negative fashion (r = -0.84, P < 0.001). The home BP level and PR were also well correlated with daytime length in a negative fashion (daytime length versus home SBP: Y = -0.79X + 134.1, r = -0.76, P < 0.001; daytime length versus home DBP: Y = -0.54X + 84.9, r = -0.87, P < 0.001; daytime length versus PR: Y = -0.16X + 65.1, r = -0.71, P < 0.001, where Y is SBP or PR and X is daytime length).

**DISCUSSION**

Previous studies have confirmed the seasonal variation of BP in patients with borderline and established essential hypertension [1-7]. We also observed an apparent seasonal variation of the home BP, but not of the office BP, in women whose office BP did not exceed 140 mmHg systole and 90 mmHg diastole during the period of observation of one year or longer. Their home BP values were below the 95th percentile values of that obtained in subjects who had been identified as normotensive by screening BP in an epidemiological survey in a community in northern Japan; those values were arbitrarily set as the upper level of normal for the home BP [15]. Thus, we assessed that the present subjects were normotensive. According to previous reports, no seasonal variation in BP occurred in normotensive subjects [4, 5]. In the present study as well, we observed no apparent seasonal variation in office BP. The relation between environmental temperature and BP has been confirmed by several authors [1-7]. The half-amplitudes of seasonal variation obtained from the 12 monthly means of daily average outdoor and indoor temperatures in the present study were 10.8°C and 7.6°C respectively, while the room temperature in the clinic where the office BP was measured was kept at 24 ± 2°C throughout the year. If environmental temperature is a decisive factor for the seasonal variation of BP, a constant environmental temperature in the clinic may account for the loss of seasonal variation of office BP. Actually Heller et al. [17] reported that a constant room temperature largely removed the effect of season on BP. Therefore, the little seasonal variation in office BP observed in the present study may be attributable, at least in part, to the constant air temperature in the clinic.

However, according to previous reports, no seasonal variation in BP occurred in normotensive sub-
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...jects [4, 5], although clinic BP was measured at an inconstant room temperature.

The differences in the method of measuring BP used in the clinic compared with that at home may also have been responsible for the different seasonal variation of BP observed in different settings. With one or two measurements of office BP a month, the seasonal BP variation may be masked by the great variability in office BP. Home BP measurements offer precise information and increase the sensitivity for detecting changes in BP [8-11], since with this method, averaging a greater number of BP measurements under fixed and non-medical conditions with an automatic device can be achieved. This is the most likely explanation for the minimal seasonal variation seen in the office BP, since the yearly variation in BP, represented as SD of yearly average office BP, was apparently higher than that of yearly average home BP. Surprisingly, in 1930, Brown [1] performed his study on seasonal variation of BP using a home BP measurement procedure. In his study, a 31-year-old hypertensive man measured his own BP for 3 years. An apparent seasonal variation in BP was observed. In the present study, home BP measurements confirmed the seasonal variation of BP in normotensive women.

It is also possible that this seasonal variation in BP is related to factors other than temperature which change with the season [3]. A seasonal variation of body weight may be postulated as a factor that affects the BP. In the present study, no seasonal change in weight was observed. Yearly variations in cardiovascular function are probably mediated by genetically fixed endogenous rhythms in relation to neuroendocrine and/or metabolic function. A seasonal variation in endocrine function and in the function of the sympathetic nervous system has been reported previously [4, 6, 18-21]. Exogenous seasonal effects such as daytime length may affect the endogenous rhythm, altering the shape and timing of seasonal variation [6]. This possibility may be supported by the present result that the highest levels of home SBP and DBP were observed at different time points; i.e. the SBP in January and the DBP in December. The lowest environmental temperature was observed in January, while the shortest day is in December. The lowest levels of home SBP and DBP were observed in July. However, the highest levels of indoor and outdoor temperature were observed in August, while the longest day is in June. These results indicate the dissociation of seasonal variation in blood pressure and environmental temperature. If environmental temperature was the sole factor involved in regulating the seasonal variation in BP, the highest DBP value should appear in January when the environmental temperature is at its lowest, and the lowest SBP and DBP values should appear in August, when the environmental temperature is at its highest. It is noteworthy that the longest daytime length preceded and the highest environmental temperature lagged behind the lowest level of BP.

A potential limitation of the present study is the lack of information on other factors influencing seasonal variation of BP such as seasonal variation in the diet (salt intake), atmospheric pressure or rainfall/sun exposure; these factors may affect the BP levels differentially according to season. The study would gain strength if subjects from other geographic areas with different daytime length are included. Further studies including such factors would be useful.

In conclusion, season had an important influence on BP, even in normotensive subjects. This finding should be kept in mind when evaluating the BP in individuals, and when conducting epidemiological studies in large populations.

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REFERENCES