Original Article

Status of Home Blood Pressure Measured in Morning and Evening: Evaluation in Normotensives and Hypertensives in Japanese Urban Population

Hiroshi KAWABE, Ikuo SAITO, and Takao SARUTA*

To assess home blood pressure status in a Japanese urban population, we analyzed home blood pressure values in normotensive subjects determined by casual blood pressure (<140/90 mmHg), hypertensive subjects without medication (≥140/90 mmHg) and treated hypertensive patients. The subjects (468 male, 232 female; mean age 41 years old) were recruited from a company located in Tokyo. Home blood pressure was measured with a semi-automatic device (Omron HEM-759P). Subjects were instructed to perform triplicate morning and evening measurements on 7 consecutive days. In the treated hypertensive group (n=70), there was a significant difference between morning (139±12/88±9 mmHg) and evening (130±12/79±8 mmHg) home blood pressure. In the normotensive group (n=558), however, only the diastolic blood pressure (DBP) component of the home blood pressure was significantly different between morning (115±13/72±9 mmHg) and evening (114±12/68±8 mmHg). In the nontreated hypertensive group (n=72), casual blood pressure (145±14/92±9 mmHg) was higher than morning (138±16/89±11 mmHg) and evening (134±16/83±11 mmHg) home blood pressure, but no difference was seen between morning and evening systolic blood pressure (SBP). According to the reference value of the Japanese Society of Hypertension 2004 (SBP ≥135 mmHg and/or DBP ≥85 mmHg), 7.2% (systolic) and 8.7% (diastolic) of subjects in the normotensive group were classified as hypertensive by home blood pressure. Casual blood pressure in the treated hypertensive group was normal in 64.3% for SBP and 70.0% for DBP. However, their morning SBP (32.9%), morning DBP (40.0%), evening SBP (10.0%), and evening DBP (17.1%) were classified as hypertensive by home blood pressure. Furthermore, patients who were taking antihypertensive drug(s) only in the morning (n=52) showed higher morning SBP (6 mmHg, p=0.086) and morning DBP (6 mmHg, p=0.005) than patients taking drug(s) by other administration schedules (n=18), but no difference in evening home blood pressure was observed. In conclusion, a proportion of the subjects defined as normotensive by casual blood pressure were classified as hypertensive by home blood pressure in the present urban population. Furthermore, morning home blood pressure control in the treated hypertensive group classified as under control by casual blood pressure was insufficient, especially in patients who were taking medication only in the morning. (*Hypertens Res* 2005; 28: 491–498)

Key Words: casual blood pressure, home blood pressure, antihypertensive drug, morning hypertension

From the Health Center and *Department of Internal Medicine, School of Medicine, Keio University, Tokyo, Japan.

Address for Reprints: Hiroshi Kawabe, M.D., Ph.D., Health Center, Keio University, 35 Shinanomachi, Shinjuku-ku, Tokyo 160−8582, Japan. E-mail: kawabe-h@viola.ocn.ne.jp

Introduction

Self-measurement of blood pressure at home has developed enormously in recent years (*1*) and is useful in raising people's concern about hypertension. In the medical management of hypertensive patients, home blood pressure measurement raises their knowledge and consciousness of hypertension, and has become one of the important means of motivating patients to take an active, positive role in their medical treatment. However, there have been few reports on the status of home blood pressure values in normotensives and hypertensive patients (*2*, *3*).

It has been reported that only a small proportion of patients on antihypertensive drugs have well controlled blood pressure (*4–6*). It has also been suggested that this apparently poor blood pressure control is caused, at least in part, by the so-called "white-coat effect," since casual blood pressure taken in medical settings was used in these studies. Home blood pressure can be used to monitor blood pressure in non-medical settings and can avoid the white-coat effect (*4*, *7*). Therefore, such a measurement may be suitable for the investigation of the true blood pressure status in the general population. However, only two studies, one in Japan (*3*) and one in Italy (*2*, *8*), have used home blood pressure to investigate blood pressure status in a general population.

In this study, according to the reference value of home blood pressure (in which hypertension is defined as a systolic blood pressure [SBP] ≥135 mmHg and/or diastolic blood pressure [DBP] ≥85 mmHg) in the guidelines of the Japanese Society of Hypertension 2004 (*9*), the status of morning and evening home blood pressure in both normotensive subjects (defined by a casual blood pressure with a SBP component <140 mmHg and a DBP component <90 mmHg, normotensive group) and hypertensive subjects receiving antihypertensive drugs (treated hypertensive group) or no medication (nontreated hypertensive group) was evaluated. Thus, we tried to clarify the proportion of subjects who are misclassified as normotensive based on casual blood pressure and to evaluate the status of the control of morning and evening home blood pressure in treated hypertensive patients in a Japanese urban population.

Methods

Study Population

The selection of study subjects has been described previously (*10*). In brief, a search for candidates was made on the intranet of a company in Tokyo, Japan. Written consent was obtained from 1,036 volunteers, which included the employees' family members, aged 20 or more years. They were registered from October 1 to 7, 2002. Subjects unsuitable for the investigation, such as shift workers (*11*), were excluded before commencement of the study. The study protocol was approved by the Institutional Review Board of the Health Center, Keio University and by the participating company.

After checking the submitted printed record of measurements, 336 subjects were excluded because of violation of selection criteria (lack of either home blood pressure or casual blood pressure values, uncertainty of the time of home blood pressure measurement, *etc*.) or violation of the predetermined protocol (starting on days other than Tuesday, Wednesday, or Thursday, or measuring home blood pressure within 30 min of bathing before going to bed, or uncertainty of the time interval from bathing to measurement, *etc*.). The remaining 700 subjects (468 male, 232 female) were adopted as subjects for the present analysis.

Blood Pressure Measurements

Casual Blood Pressure Measurement

Casual blood pressure was measured while the subjects were seated, after an at least 2-min rest. Measurement was performed one to three times using a mercury sphygmomanometer. As a rule, participants underwent casual blood pressure measurement at the clinic within 1 month before or after the period of home blood pressure measurement. The blood pressure value measured at the time of a medical checkup during the above period was also accepted as casual blood pressure.

Home Blood Pressure Measurement

Home blood pressure measurement was performed in the following manner between October 16 and November 13, 2002. A new semi-automatic device (HEM-759P; Omron Life Science Co. Ltd., Tokyo, Japan) based on the cuff-oscillometric principle was lent to all registrants, and they were asked to perform triplicate morning and evening measurements in the sitting position after at least 2 min of rest on 7 consecutive days. The circumference of the arm was less than 32 cm in most cases, so we used a standard arm cuff for both home blood pressure and casual blood pressure measurements. The morning measurement was made within 1 h after rising, and was carried out before breakfast and after urination (*12*). If individuals were taking antihypertensive drugs, blood pressure was measured before taking the medication (*12*). When performing measurement before going to bed, on the other hand, in order to avoid measurement within 30 min after bathing, subjects were instructed to record the time elapsed since bathing. The record printed out by a printer attached to the semi-automatic sphygmomanometer was stuck on the survey form and submitted. Even if a value considered to be abnormal was acquired, we instructed the subject beforehand not to perform measurement more than three times. Measurement started on Tuesday, Wednesday, or Thursday.

Since a significant difference was seen between the first home blood pressure value and the second or third value in our previous study (*10*), the average of the second and third values was adopted as the value for analyses. The home blood pressure value of an individual was defined as the mean of

Table 1. Background Factors of Subjects

	Normotensive group	Nontreated hypertensive group	Treated hypertensive group
Number of subjects	558	72	70
Male/female	357/201	56/16*	55/15*
Age (years)	38±10	47±9**	54±8**,‡
Height (cm)	167.0±8.4	167.1±8.5	165.6±7.8
Body weight (kg)	62.5±11.9	69.0±13.4**	67.6±11.2**
Body mass index (kg/m^2)	22.2±2.9	24.6±3.3**	24.5±2.6**
Casual systolic BP (mmHg)	116±12	145±14**	136±12**,‡
Casual diastolic BP (mmHg)	71±9	92±9**	84±8**,‡
Drinking habit (%)	54.3	59.7	68.6*
Smoking habit (%)	20.3	30.6	20.0
Hyperlipidemia (%)	11.3	22.2**	28.6**
Diabetes mellitus (%)	1.3	1.4	12.9**,‡
Angina pectoris (%)	0.2	1.4	1.4
Experience of home BP measurement (%)	7.3	25.0**	65.7**,‡

Values are mean±SD. *$p<0.05$, **$p<0.01$ *vs.* normotensive group, ‡$p<0.01$ *vs.* nontreated hypertensive group. BP, blood pressure.

measurements on days 2 to 7, since home blood pressure on the first day was significantly higher than that on the second day in our previous study (*10*).

Classification of Subjects

We classified the subjects into three groups according to their casual blood pressure values and their use of antihypertensive medications as follows: normotensive group (*n*=558, subjects who had never taken antihypertensive medication and whose casual blood pressure was <140 mmHg for systolic and <90 mmHg for diastolic); nontreated hypertensive group (*n*=72, subjects who had never taken antihypertensive medication and whose casual blood pressure was ≥140 mmHg for systolic and/or ≥90 mmHg for diastolic); and treated hypertensive group (*n*=70, subjects who were being treated with antihypertensive medication).

Home Blood Pressure Criteria for Hypertension

We classified the subjects with home blood pressure ≥135 mmHg (systolic) and/or ≥85 mmHg (diastolic) as hypertensive. This cut-off level of 135/85 mmHg was based on the Japanese Society of Hypertension 2004 criteria (*9*).

Data Analysis

Values are expressed as the mean±SD. Differences in mean values between two groups were determined by a two-tailed unpaired Student's *t*-test or Mann-Whitney *U* test, and the χ^2-test was also used as appropriate. The difference between casual blood pressure and home blood pressure (morning and evening) was examined using one-way analysis of variance

and Scheffe's multiple comparison method. For prediction of morning home blood pressure and evening home blood pressure in the treated hypertensive group, potential variables entered into the models included age, sex, body mass index, casual blood pressure, and method of administration. In the applied model of stepwise linear regression, a 5% significance level was used as the criterion for inclusion in the model. Values of $p<0.05$ were considered to indicate statistical significance. All statistical analyses were performed using SAS® version 8.2 software.

Results

Background (Table 1)

The male/female ratio of all subjects was about 2 to 1, but the nontreated hypertensive and treated hypertensive groups had more male patients. The mean age of all subjects was 41 years old (range, 20 to 84 years old) and those of the nontreated hypertensive and treated hypertensive groups were older. More than one half of subjects drank alcohol and about 20% smoked. In addition, 15% of all subjects had performed home blood pressure measurement in the past and more than one half of the treated hypertensive group had experienced home blood pressure measurement.

Relationship between Casual Blood Pressure and Morning Home Blood Pressure or Evening Home Blood Pressure (Fig. 1)

There was no significant difference between SBP measured in the clinic and SBP measured at home in the normotensive group. SBP measured in the clinic was higher than SBP mea-
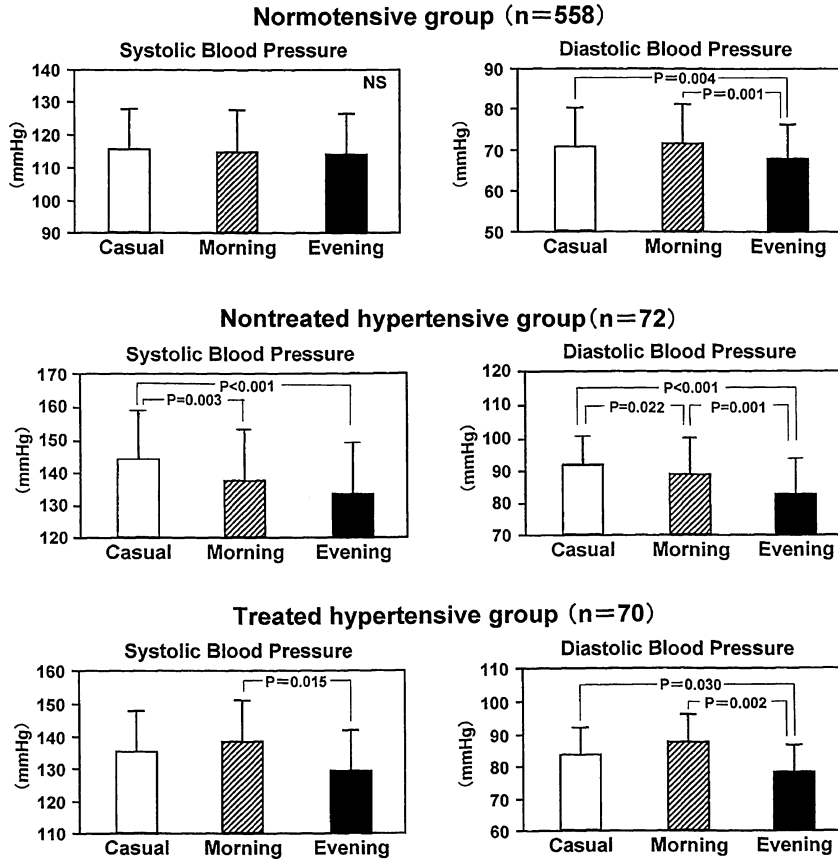
Normotensive group (n＝558)

Fig. 1. *Relationship between casual blood pressure and home blood pressure in morning or evening. NS, not significant.*
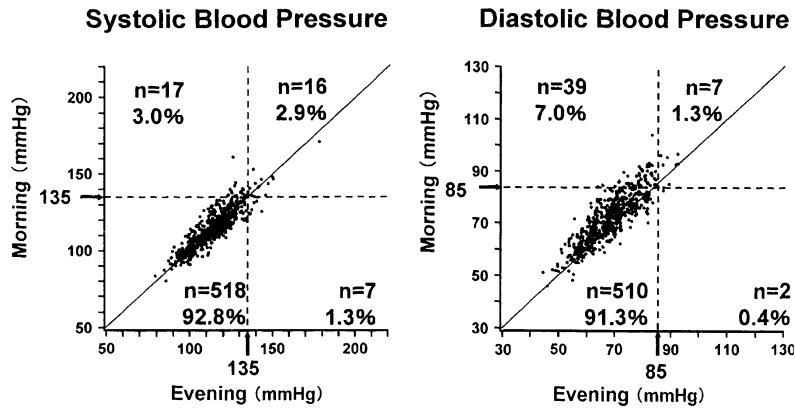

Fig. 2. *Home blood pressure status in the normotensive group (n＝558).*

sured at home in the nontreated hypertensive group, but there was no significant difference between morning and evening SBP. However, morning SBP was highest in the treated hypertensive group, and there was a significant difference between morning and evening SBP in the treated hypertensive group. On the other hand, a similar pattern was observed in DBP in the three groups. Namely, evening DBP in the three groups was the lowest, and we found a significant difference between evening DBP and casual or morning DBP. In the nontreated hypertensive group, we also found a significant difference between casual DBP and morning DBP.
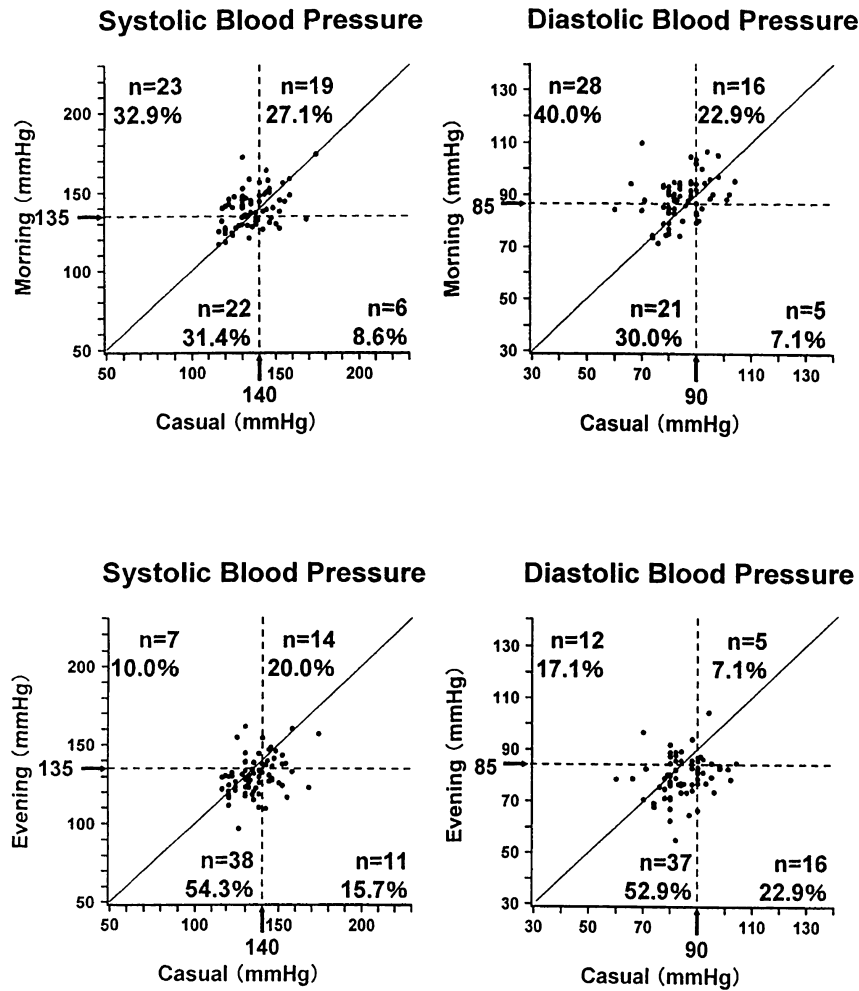
Fig. 3. *Casual and home blood pressure control in the treated hypertensive group (*n*= 70).*

Home Blood Pressure Status in the Normotensive Group

When morning and evening home blood pressure values were plotted, 7.2% of the normotensive group had a home blood pressure ≥135 mmHg for systolic and 8.7% had a home blood pressure ≥85 mmHg for diastolic in either the morning or evening (Fig. 2).

Home Blood Pressure Status in the Nontreated Hypertensive Group

When morning and evening home blood pressure values were plotted, 34.7% of the nontreated hypertensive group had a home blood pressure <135 mmHg for systolic and 29.2% had a home blood pressure <85 mmHg for diastolic in both the morning and evening.

Casual Blood Pressure and Home Blood Pressure Control in the Treated Hypertensive Group (Fig. 3)

When casual blood pressure and morning home blood pressure were plotted in the treated hypertensive group, 64.3% of patients had casual blood pressure <140 mmHg for systolic and 70.0% had casual blood pressure <90 mmHg for diastolic. However, even if casual blood pressure was controlled, we found that 32.9% of patients had morning SBP ≥135 mmHg and 40.0% had morning DBP ≥85 mmHg. Similarly, when casual blood pressure and evening home blood pressure were plotted, 10.0% of patients showed evening SBP ≥135 mmHg and 17.1% showed evening DBP ≥85 mmHg, even if casual blood pressure was controlled under 140 mmHg for systolic and 90 mmHg for diastolic.
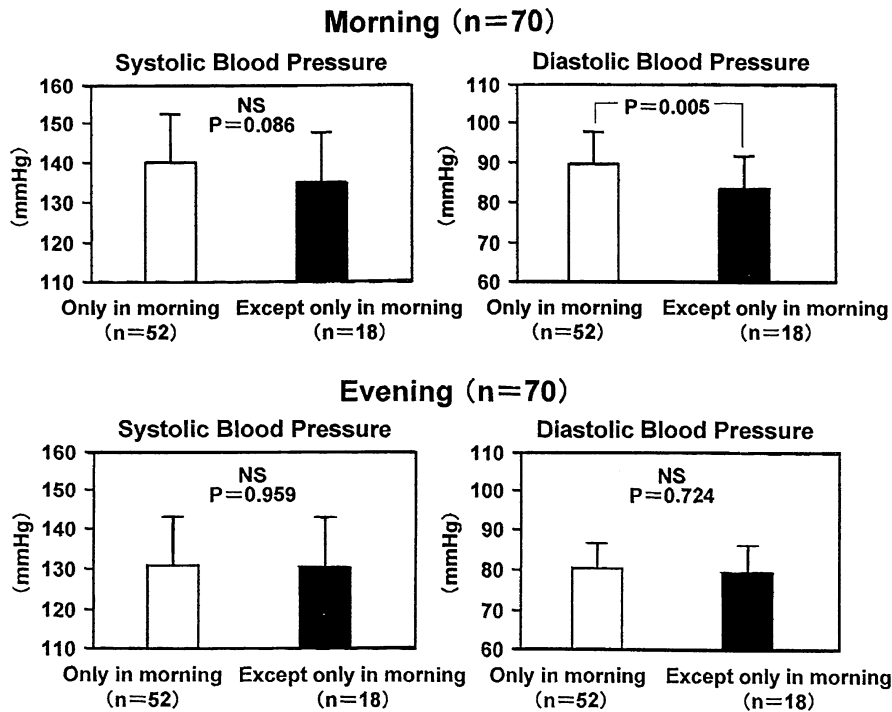
Morning (n=70)

Fig. 4. *Relationship between method of administration and home blood pressure control in the treated hypertensive group. NS, not significant.*

Relationship between Method of Administration and Home Blood Pressure Control in the Treated Hypertensive Group

In order to evaluate the influence of the method of administration on home blood pressure control, we divided the treated hypertensive group into two subgroups: patients who were taking antihypertensive drugs only in the morning (*n*=52) and all other patients (*i.e.*, all patients but those taking drugs only in the morning) (*n*=18).

In patients receiving antihypertensive drugs only in the morning, calcium antagonists were most often used (67%), followed by angiotensin II receptor blockers (40%). In the patients receiving drugs according to other administration schedules, calcium antagonists (67%) were also most often used, followed by angiotensin II receptor blockers (20%).

Patients who were taking drugs only in the morning showed higher morning SBP (6 mmHg, *p*=0.086) and morning DBP (6 mmHg, *p*=0.005) than patients taking drugs by other administration schedules, and a significant difference in morning DBP was observed between the two (Fig. 4). On the other hand, there was no difference in evening home blood pressure between the two subgroups (Fig. 4).

Table 2 shows the findings of the stepwise linear regression analysis for predicting morning and evening home blood pressure in the treated hypertensive group. The best predictors of higher morning DBP were the method of administration (only in the morning), higher body mass index, younger

age, and male sex. Variations of all the above-mentioned factors could explain 35.5% of the variation in morning DBP in the treated hypertensive group. Higher levels of morning SBP were best predicted by higher casual SBP and male sex. Together, the two factors listed above predicted 28.1% of the variation in morning SBP in the treated hypertensive group.

Discussion

In the present examination, evening home blood pressure values were lower than morning home blood pressure values, except for SBP in the normotensive and nontreated hypertensive groups. Moreover, even when the subjects were classified into the normotensive group by casual blood pressure measurement, 7.2% (systolic) and 8.7% (diastolic) were classified as hypertensive by home blood pressure measurement. Furthermore, the status of the control of morning home blood pressure in the treated hypertensive group was inadequate even if casual blood pressure was controlled, and it was notable in the patients who were taking antihypertensive drug(s) only in the morning.

In this study, the evening home blood pressure values were lower than the morning home blood pressure values, with the exception of the SBP component, in the normotensive and nontreated hypertensive groups. In the population study in Ohasama, Japan (*3, 13*), evening SBP was also lower than morning SBP by 2 mmHg. While some European and American reports (*14*) have shown a pattern similar to that of the

Table 2. Standardized Regression Coefficients and Coefficients of Determination in the Stepwise Linear Regression Models for Predicting Home SBP and DBP in Morning and Evening from Variables Measured in Treated Hypertensive Patients

Independent variables	Standardized regression coefficient
Morning SBP	
Casual SBP	0.486
Male	0.293
Coefficient of determination=0.281	
Morning DBP	
Taking drug(s) only in the morning	0.299
Body mass index	0.279
Age	−0.235
Male	0.228
Coefficient of determination=0.355	
Evening SBP	
Casual SBP	0.339
Coefficient of determination=0.115	

SBP, systolic blood pressure; DBP, diastolic blood pressure.

present study, other reports have shown a higher evening home blood pressure than morning home blood pressure (*15*, *16*). This difference might be mainly caused by the time of blood pressure measurement; European studies measured night blood pressure at early evening, but our study measured it at late evening. Evening bathing and drinking, both of which are customs among Japanese, might also be considered, since both behaviors cause a transient fall in blood pressure (*17*). Usually, environmental factors, such as the behavioral pattern of daily life, have a large influence on evening home blood pressure. In this study, patients were instructed to perform home blood pressure measurement at least 30 min after bathing, but abstinence from alcohol was not enforced. It is generally considered that blood pressure is low several hours after drinking (*17*), and this influence needs to be considered in interpreting our present results.

We demonstrated that 7.2% (systolic) and 8.7% (diastolic) of the normotensive group could be classified as hypertensive by home blood pressure measurement using Japanese Society of Hypertension 2004 criteria (*9*); ≥135 mmHg for SBP and/or ≥85 mmHg for DBP. Recently, Hozawa *et al*. (*3*) have also reported that when they classified normotensive subjects according to JNC VI criteria for home blood pressure (*4*), about 10% of normotensive subjects were classified as hypertensive on the basis of home blood pressure measurement. Therefore, the existence of a condition similar to the so-called "reverse white-coat hypertension" (*18*) or "masked hypertension" (*19*) revealed by 24-h ambulatory blood pressure monitoring is assumed.

Although the number of treated hypertensive patients was small, we examined the status of the control of home blood

pressure as well as casual blood pressure. In casual blood pressure measurement, SBP was controlled to under 140 mmHg in 64.3% of patients, and DBP was controlled to under 90 mmHg in 70.0% of patients. However, even in these controlled hypertensives, it became clear that the control of morning home blood pressure and evening home blood pressure was insufficient. It has been reported that 49% of hypertensive patients under treatment with antihypertensive drugs in the Ohasama study had morning hypertension (*3*). Furthermore, Mancia *et al*. (*2*) reported that 64% of treated hypertensive patients in the PAMELA population were classified as hypertensive by ambulatory blood pressure measurement. Thus, we divided the treated hypertensive group into two subgroups and evaluated the status of their control of home blood pressure. Patients who were taking medication only in the morning clearly showed a worse control status of morning home blood pressure than patients taking medication according to other administration schedules. Furthermore, the best predictor of higher morning DBP in the treated hypertensive group was the method of administration (*i.e.*, administration only in the morning). This finding suggests that the duration of the hypotensive effect is not adequate when antihypertensive medication is administered only in the morning. Administration of antihypertensive drug(s) once a day is the current mainstream practice, and almost all hypertensive patients take medication after breakfast. However, there is a possibility that the effectiveness of this kind of administration is inadequate for some treated hypertensives and that morning hypertension cannot be avoided. Therefore, it is expected that the home blood pressure value will become a powerful parameter that can be used to determine the appropriate antihypertensive drug(s) with respect to the best duration for each patient (*20*) and the most effective administration schedule (*21*).

In interpreting our present findings, there are several study limitations that should be considered. First, we adopted only one value measured within 1 month before or after the period of home blood pressure measurement as casual blood pressure, since almost subjects were healthy normotensives. Therefore, the influence of the white-coat effect may have been strong (*22*), and there is a possibility that some white-coat hypertensives were included in the nontreated hypertensive group. Second, we took three home blood pressure measurements on each occasion in this study. Since the first value was significantly higher than the second and third values, the average of the second and third values was adopted as the home blood pressure value at each measurement point (*10*). Furthermore, since the value on the first day was significantly higher than that on the second day, we adopted the average value for 6 days (*i.e.*, from the second to the seventh day) as the blood pressure for each individual (*10*). However, there is a possibility that our home blood pressure value was underestimated, since we discarded the higher first value (122±17/76±12 mmHg and 120±15/72±10 mmHg for the first value of morning and evening, and 119±16/75±12 mmHg and 118±15/71±10 mmHg for the average of the second and

third values of morning and evening). Third, although the number of treated hypertensive patients was small, they were randomly sampled, and the type and frequency of the antihypertensive drugs were mostly in agreement with the present status in the general Japanese hypertensive population (*23*).

In conclusion, even when casual blood pressure was normal, hypertension was seen in a certain proportion of the present subjects based on home blood pressure. Moreover, the status of the control of morning home blood pressure in some hypertensive patients who were taking antihypertensive drug(s) was inadequate even if casual blood pressure was well controlled. This was especially notable in patients who were taking antihypertensive drug(s) only in the morning. These findings are expected to be key for the future selection of antihypertensive drugs and their administration regimens.

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