Self-measured versus ambulatory blood pressure in the diagnosis of hypertension

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Objective **We examined to what extent self-measurement of blood pressure at home (HBP) can be an alternative to ambulatory monitoring (ABP) to diagnose white-coat hypertension.**

Methods **In 247 untreated patients, we compared the white-coat effects obtained by HBP and ABP. The thresholds to diagnose hypertension were ⩾ 140/⩾ 90 mmHg for conventional blood pressure (CBP) and ⩾ 135/⩾ 85 mmHg for daytime ABP and HBP.**

Results **Mean systolic/diastolic CBP, HBP and ABP were 155.4/100.0 mmHg, 143.1/91.5 mmHg and 148.1/95.0 mmHg, respectively. The white-coat effect was 5.0/3.5 mmHg larger on HBP compared with ABP (12.3/8.6 versus 7.2/5.0 mmHg; $P < 0.001$). The correlation coefficients between the white-coat effects based on HBP and ABP were 0.74 systolic and 0.60 diastolic ($P < 0.001$). With ABP as a reference, the specificity of HBP to detect white-coat hypertension was 88.6%, and the sensitivity was 68.4%.**

Conclusion **Our findings are in line with the recommendations of the ASH Ad Hoc Panel that recommends HBP for screening while ABP has a better prognostic accuracy.** ***J Hypertens*** **21:1–6 © 2003 Lippincott Williams & Wilkins.**

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Introduction

Automated techniques of blood pressure measurement are used increasingly to diagnose hypertension. Compared with conventional blood pressure measurement by the Korotkoff method, these newer techniques are more reproducible and not subject to digit preference or observer bias. Ambulatory blood pressure measurements refines the prediction of cardiovascular complications already provided by conventional sphygmomanometry [1,2]. However, ambulatory monitoring requires considerable investment in hardware, software and training of operators [3]. Recently, several devices for the self-measurement of blood pressure have successfully passed validation [4]. Compared with ambulatory monitoring, self-measurement at home is less expensive, less cumbersome and has the potential of improving the patients' compliance to treatment [5]. There are strong theoretical arguments in favour of blood pressure measurement at home. Nevertheless, to design practical guidelines for clinicians, more information is needed concerning the application of the technique (e.g. number of measurements, day-to-day variability, etc.) and on its diagnostic accuracy.

The main objective of the Treatment of Hypertension According to Home or Office Blood Pressure (THOP) trial is to test the hypothesis that antihypertensive drug treatment guided by self-measured blood pressure may be more beneficial to patients than treatment based on conventional blood pressure readings by the doctor [6]. The trial is still ongoing, but recruitment has been completed. Baseline data on the conventional, ambulatory and self-measured home blood pressures are available. The aim of the present analysis was to investigate whether self-measurement of blood pressure at home can be used as an alternative to ambulatory blood

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pressure monitoring to assess the white-coat effect and to diagnose hypertension.

Methods

The protocol of the multicentre THOP trial has been described in detail elsewhere [6]. Blood pressure measurements at baseline were available from 475 hypertensive patients whose sitting diastolic blood pressure was 95 mmHg or higher on conventional measurement (mean of two visits during a one-month run-in period).

Conventional blood pressure was measured by the doctor with a standard mercury sphygmomanometer at two office visits scheduled at an interval of 2–3 weeks. Each time, three blood pressure readings were obtained after the patient had rested for 5 min in the sitting position. The ambulatory blood pressure was recorded between the two office visits with oscillometric SpaceLabs 90207 monitors (SpaceLabs Inc., Redmond, Washington, USA). The devices were programmed to obtain blood pressure readings at 15-min intervals from 08.00 to 22.00 h and at 30-min intervals for the remainder of the day. Daytime and night-time ambulatory blood pressures were calculated as the time-weighted means of the readings obtained from 10.00 to 20.00 h and from 00.00 to 06.00 h, respectively [7]. For the self-measurement of blood pressure at home, the patients used Omron HEM-705CP (Omron Corp., Tokyo, Japan) digital blood pressure monitors. This automated oscillometric device measures brachial artery pressure and has successfully passed validation according to the protocol of the British Hypertension Society [8,9]. At enrolment, the doctor or the study nurse instructed the patients how to use the Omron recorders and provided written guidelines for their operation at home. The patients recorded their blood pressure in the morning (between 06.00 and 10.00 h) and in the evening (between 18.00 and 22.00 h) during the week immediately preceding their second clinic visit. Each measurement session consisted of three readings after 5 min rest in the sitting position. Self-measured blood pressure values were printed, kept in a diary and at the next office visit, checked by the physician who enquired about circumstances that could explain exceptionally high or low readings. For all types of blood pressure measurement, the same cuff size was used. Standard cuffs had a 24×14 cm inflatable bladder. If arm circumference exceeded 31 cm, larger cuffs with a bladder size of 32×15 cm were used.

The white-coat effect was defined as the difference between conventional and daytime ambulatory blood pressure or the difference between conventional and average home blood pressure. The blood pressure thresholds indicating hypertension were $\geqslant 140/\geqslant 90$ mmHg for the conventional blood pressure and $\geqslant 135/\geqslant 85$ mmHg for the daytime ambulatory as well as the home blood pressure [10]. Because white-coat hypertension can only be diagnosed in untreated patients, of 475 patients screened, we excluded 218 who were currently taking antihypertensive drugs.

Database management and statistical analysis were performed with SAS software, version 8.1. For comparisons, we used Student's *t*-test or analysis of variance for continuous variables and the chi-square statistic for proportions. As a measure of agreement, we calculated the κ coefficient. We considered the percentage of white-coat hypertensives diagnosed by ambulatory monitoring as the reference to determine sensitivity, specificity, and the positive and negative predictive values associated with the application of self-measurement. All statistical tests were two-sided.

Results

Characteristics of patients at baseline

The study group included 257 untreated hypertensive patients of whom 118 (45.9%) were male, 56 (21.8%) were smokers and 93 (36.2%) reported alcohol intake on a regular basis (at least seven drinks per week). Other patient characteristics, including blood pressure values, are given in Table 1.

Self-measured home blood pressure

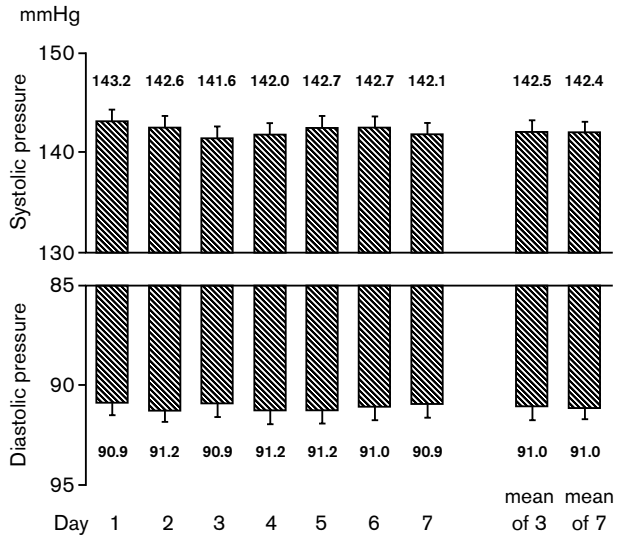
Figure 1 shows how the blood pressure at home varied on seven consecutive days of measurement. There was no significant overall difference over time, no significant difference between the first and second day, or between the mean of the first three days and the mean of the whole week. Home blood pressure was signifi-

Table 1 Patient characteristics at baseline

Variable	Mean ± SD
Age (years)	50.4 ± 11.0
Body-mass index (kg/m⩽)	27.4 ± 4.3
Serum total cholesterol (mmol/l)	5.70 ± 1.03
Serum creatinine (μmol/l)	84.6 ± 17.4
Conventional blood pressure	
systolic (mmHg)	155.4 ± 16.2
diastolic (mmHg)	100.0 ± 6.9
24-h blood pressure	
systolic (mmHg)	140.4 ± 13.1
diastolic (mmHg)	88.6 ± 8.6
Daytime blood pressure	
systolic (mmHg)	148.1 ± 14.2
diastolic (mmHg)	95.0 ± 9.3
Night-time blood pressure	
systolic (mmHg)	127.6 ± 13.9
diastolic (mmHg)	78.2 ± 9.6
Home blood pressure	
systolic (mmHg)	143.1 ± 16.1
diastolic (mmHg)	91.5 ± 9.0

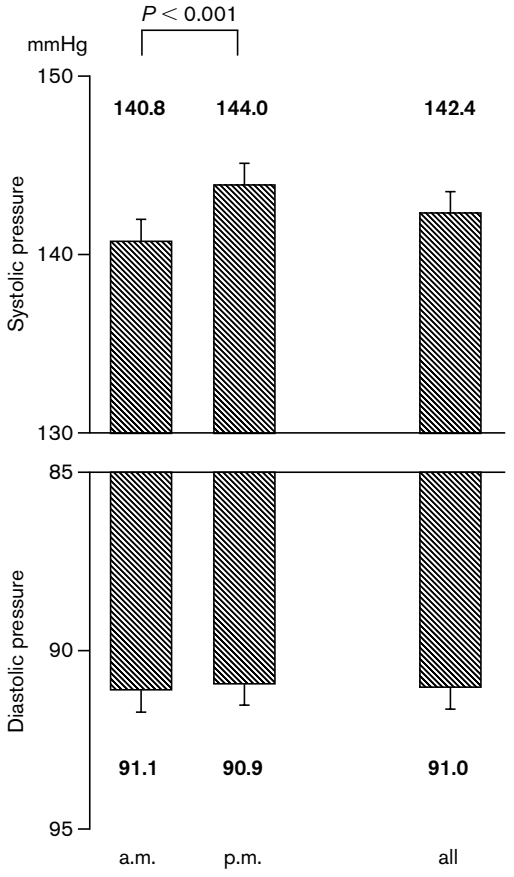
Conventional blood pressure was the mean of six readings in the sitting position, i.e. three readings obtained at each of two office visits. 24-h, daytime and night-time blood pressures were calculated from ambulatory recordings. Home blood pressure is the mean of 42 readings in the sitting position, i.e. three in the morning and three in the evening during seven consecutive days.

Fig. 1



Systolic and diastolic self-measured blood pressures during seven consecutive days (mean of morning and evening measurements).

Fig. 2



Systolic and diastolic self-measured home blood pressure in the morning and in the evening (mean of 7 days).

cantly higher in the evening compared with the morning for systolic pressure ($P < 0.001$), but not for diastolic pressure (Fig. 2). In further analyses, we used the mean of all available self-measurements (7 days, morning and evening).

White-coat effect

Systolic and diastolic white-coat effects were larger on self-measurement than on ambulatory monitoring. The differences were 5.0 mmHg (95% CI = 3.8–6.3; $P < 0.001$) systolic (12.3 ± 13.9 versus 7.2 ± 13.8) and 3.5 mmHg (95% CI = 2.7–4.4; $P < 0.001$) diastolic (8.6 ± 8.2 mmHg versus 5.0 ± 8.9 mmHg). The correlation coefficients between the white-coat effects based on home and daytime blood pressure were 0.74 systolic and 0.60 diastolic ($P < 0.001$) (Fig. 3).

Diagnosis of hypertension

Inclusion in the study was based on the conventional blood pressure readings of two office visits. However, 10 patients were not hypertensive based on the measurements of the last visit only and therefore are not included in the classification of white-coat hypertensives (Table 2).

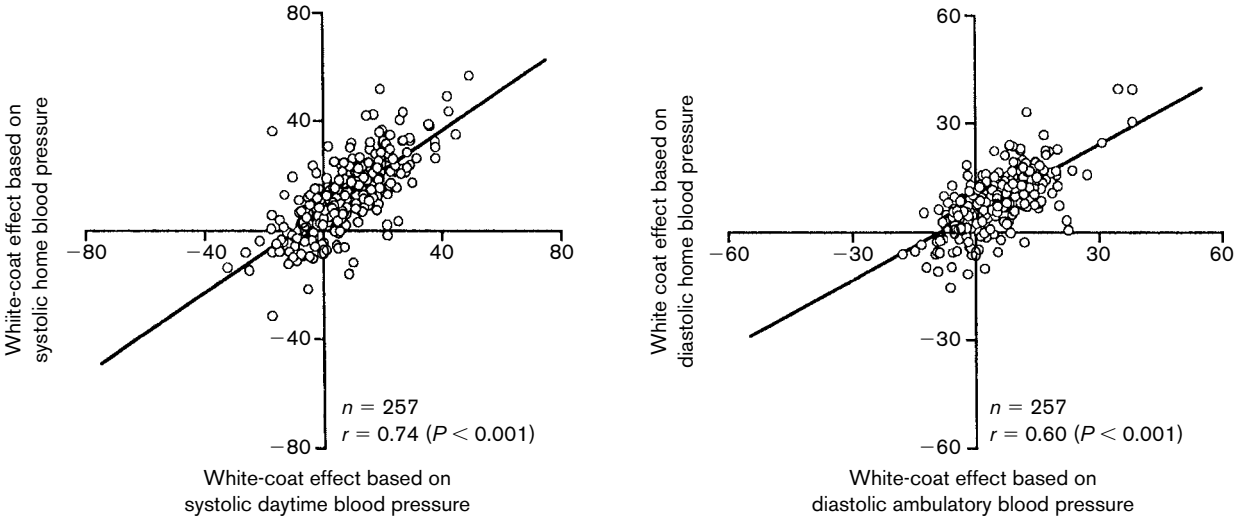
Of 247 patients with hypertension on conventional measurements, 215 (87.0%) were consistently classified as white-coat or sustained hypertensives regardless of whether their daytime ambulatory or self-measured blood pressure was considered (Table 2). The κ-coefficient of 0.38 (95% CI: 0.22–0.55) reflected moderate agreement. With ambulatory blood pressure taken as the standard, home blood pressure showed a high specificity and negative predictive value but a low sensitivity and positive predictive value to classify white-coat hypertensives (Table 2).

Discussion

The present analysis demonstrated that under standardized conditions of measurement, the white-coat effects based on the daytime ambulatory monitoring and self-measurement were closely correlated. Nevertheless, the white-coat effect was slightly, but significantly, greater when assessed in the relaxed home environment than during daytime ambulatory monitoring. To diagnose white-coat hypertension, the self-measured blood pressure had a higher sensitivity but a lower specificity than the daytime ambulatory blood pressure.

Three days and one week of consecutive self-measurement yielded similar blood pressure values and thus provided comparable diagnostic information. The shorter period can therefore be recommended for clinical practice. Although the difference was not significant, we did find a higher systolic blood pressure on the first

Fig. 3



Correlation between the white-coat effects (mmHg) on self-measurement versus ambulatory monitoring for systolic (left) and diastolic (right) blood pressure.

Table 2 Sustained and white-coat hypertension according to ambulatory monitoring versus self-measurement of blood pressure

	Daytime ambulatory blood pressure	
	White-coat hypertension	Sustained hypertension
Home blood pressure		
White-coat hypertension	$n = 13$ (5.3%)	$n = 26$ (10.5%)
Sustained hypertension	$n = 6$ (2.4%)	$n = 202$ (81.8%)

The κ-coefficient was 0.38 (95% CI: 0.22–0.55). With daytime blood pressure as a reference, sensitivity was 68.4%, specificity was 88.6%, and positive and negative predictive values were 33.3% and 97.1%.

day of self-measurement. Thus, as other investigators, [11–14] we do not recommend that self-measurement should be performed for fewer than 3 days. Furthermore, in agreement with published studies [12,15], we also noticed a significantly higher home blood pressure in the evening than in the morning. Thus, it is relevant to record the home blood pressure at different times of the day, for instance at 12-h intervals, to detect differences due to physical activity or intake of medication.

In a meta-analysis of 19 studies, Fagard *et al.* [1] found that left ventricular mass correlated significantly ($P < 0.001$) better with systolic ambulatory blood pressure ($r = 0.50$ [95% CI: 0.45–0.54]) than with systolic conventional blood pressure ($r = 0.35$ [0.30–0.40]). The strength of the relationship between left ventricular mass and conventional blood pressure increases when more readings are obtained at repeated occasions and in well-standardized conditions. We presume that the same principle might apply to home blood pressure. Some well-conducted studies found a significant relation between left ventricular mass and blood pressure measured at home [16], whereas other investigators, who used non-validated devices [12] or collected home readings only for 1 day [17], did not detect such associations.

Taking ambulatory blood pressure as the reference method, we found for self-measurement a high specificity but low sensitivity in the diagnosis of white-coat hypertension. The kappa coefficients indicated moderate agreement between the two measurement techniques. This is in accordance with previous studies [13,18]. We suggest that a combination of various measurement techniques might be the best approach to diagnose hypertension. Our findings support the strategy proposed by the Ad Hoc Panel of the American Society of Hypertension [19]. These guidelines recommend that patients without target organ damage but with a persistently raised office blood pressure should engage in blood pressure self-measurement. If the home blood pressure is elevated, treatment can be started and monitored on the basis of office and home measurements. In contrast, if the home blood pressure is normal, ambulatory blood pressure monitoring is advised, because of its better-documented prognostic accuracy.

Home devices are easy to use and relatively cheap to buy (between 30 and 150€). The sales of electronic home blood pressure monitors is increasing worldwide and is expected to grow in the future [5]. There is an urgent need for a generally accepted protocol for the application of blood pressure self-measurement in clin-

ical practice. Consensus should be feasible given the current experience with the measurement techniques (number of measurements, time of the day, etc), the availability of validated devices [4], and the clinical relevance of home-measured blood pressure in cross-sectional analyses studying the relationships with target organ damage. However, only one population-based study documented the long-term prognostic significance of the self-measured blood pressure. It showed that, in a Japanese population, home blood pressure measurement was a better predictor of subsequent mortality than conventional blood pressure measurement. Thus, the clinical significance of home blood pressure in terms of morbidity and mortality still needs further clarification.

In conclusion, the white-coat effects based on daytime ambulatory monitoring and self-measurement at home are correlated. Nevertheless, both techniques of automated blood pressure measurement identify different subsets of white-coat hypertensive patients. These findings suggest that self-measurement cannot replace ambulatory monitoring, but that both techniques have supplementary roles in the diagnosis of hypertension.

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Appendix: The Treatment of Hypertension According to Home or Office Blood Pressure (THOP) Study Group

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